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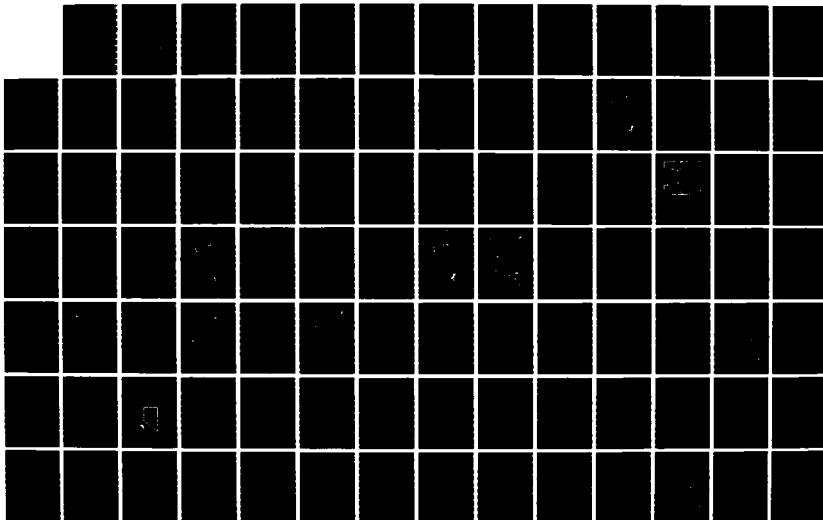
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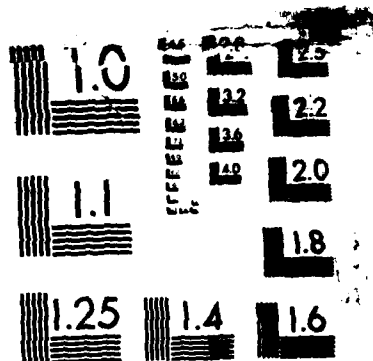
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**INSTALLATION RESTORATION PROGRAM  
PHASE II - CONFIRMATION/QUANTIFICATION  
STAGE 1**

**VOLUME 1 - TECHNICAL REPORT**

*FOR*

**CASTLE AIR FORCE BASE, CALIFORNIA**

*PREPARED BY:*

**Roy F. Weston, Inc.  
West Chester, Pennsylvania 19380**

*NOVEMBER, 1985*

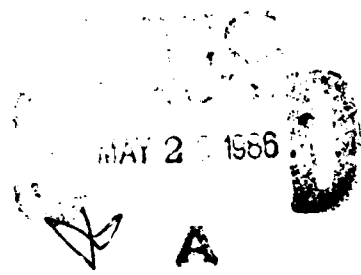
**FINAL REPORT FOR PERIOD OCTOBER 1984 TO APRIL 1985**

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*PREPARED FOR*

**HEADQUARTERS STRATEGIC AIR COMMAND  
COMMAND SURGEON'S OFFICE (HQ SAC/SGPB)  
BIOENVIRONMENTAL ENGINEERING DIVISION  
OFFUTT AIR FORCE BASE, NEBRASKA 68113**

**UNITED STATES AIR FORCE  
OCCUPATIONAL & ENVIRONMENTAL HEALTH LABORATORY (USAF OEHL)  
TECHNICAL SERVICES DIVISION (TS)  
BROOKS AIR FORCE BASE, TEXAS 78235-5501**



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FIELD	GROUP	SUB GR										
19. ABSTRACT (Continue on reverse if necessary and identify by block number) <p>-A problem confirmation study was performed at Castle AFB and included 21 potential contaminant source sites identified in the Phase I Report as requiring field investigation. The potential source sites were grouped into 16 investigation sites including the area of a confirmed plume of TCE contamination in groundwater. The field investigations, conducted from October 1984 to April 1985 included installation of 27 new monitor wells and 11 shallow lysimeters, collection of sediment samples from surface soil, shallow borings, and drainage ditches, geophysical surveys of three sites, two rounds of surface and groundwater sampling and water level measurements, and pilot test operations on a Base production well. Analytes include volatile organic compounds, TOC, TOX, oil and grease, as well as phenols, nitrate, metals, pesticide and herbicides at selected sites. Of the sixteen sites investigated, twelve were recommended for further groundwater study, either through continued monitoring of existing wells, or through expansion of the monitoring network. The TCE plume in the shallow aquifer was delineated and recommended for immediate (con't. on back)</p>												
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feasibility study; additional investigation to locate the source of the plume and to define its extent in off-Base areas and in an underlying aquifer have also been recommended.

*Part of this is Introduction  
Environmental Setting; Field Program.*

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PHASE II - CONFIRMATION/QUANTIFICATION  
STAGE 1

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PREPARED BY:

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TECHNICAL SERVICES DIVISION (TS)  
BROOKS AIR FORCE BASE, TEXAS 78235-5501

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## PREFACE

Roy F. Weston, Inc. (WESTON) has been retained by the United States Air Force Occupational and Environmental Health Laboratory (OEHL) under Contract No. F33615-84-D-4400 to provide general engineering, hydrogeological, and analytical services. These services were applied to a hydrogeologic investigation of former waste disposal sites and potential groundwater contamination at Castle Air Force Base, California.

This work was accomplished between October 1984 and April 1985. Captain Robert W. Bauer, Technical Services Branch, of the USAF Occupational and Environmental Health Laboratory (OEHL) was the principal point of contact during the project. The program was managed through the Roy F. Weston, Inc. (WESTON) home office in West Chester, Pennsylvania. Peter J. Marks was the program manager and Frederick Bopp III, Ph.D., P.G. was the project manager. In April 1985, Katherine A. Sheedy, P.G., became project manager. Alison L. Dunn, P.G., was the technical team leader for this project.

WESTON wishes to acknowledge the help of Castle AFB, particularly the Base Bioenvironmental Engineering and Civil Engineering offices, for assistance in all phases of the field work. EDAW, Inc., of San Francisco, kindly provided preliminary copies of the 1984 Comprehensive Plan-Base Layout, which was used as a base for most of the graphics in this report.



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## EXECUTIVE SUMMARY

### PROGRAM HISTORY AT CASTLE AIR FORCE BASE

Roy F. Weston, Inc. (WESTON) had been retained by the United States Air Force Occupational and Environmental Health Laboratory (OEHL) under Contract Number F33165-80-D-4006 to provide general engineering, hydrogeological, and analytical services on a task order basis. The Phase I, Problem Identification/Records Search for Castle Air Force Base was accomplished by Engineering Sciences, Inc. (ESI, 1983); the Phase I report identified 37 potential sources of contamination grouped into 26 potential source sites for the purposes of HARM score ranking. In response to the findings contained in the ESI Phase I Final Report for CAFB, the OEHL issued Task Order 0032 to WESTON, directing that a presurvey be conducted at CAFB. The purpose of this presurvey was to obtain sufficient information to develop a work scope and cost estimate for the conduct of a full Phase II, Stage 1, Problem Confirmation Study at CAFB. The presurvey site inspection was conducted at CAFB by two WESTON personnel and a representative of OEHL on 28 February 1984, and the Presurvey Report was submitted in March 1984.

In September 1984 WESTON was issued a new contract (Contract Number F33615-84-D-4400) by OEHL. Following modifications in the scope of work proposed in the Presurvey Report, Task Order 0002 under the new contract was issued. This task order authorized a Phase II, Stage 1, Problem Confirmation Study at 21 of the 26 potential source sites at CAFB identified in the Phase I Final Report (ESI, 1983). For the purposes of remedial investigation, the remaining 21 potential source sites were grouped into 15 investigation sites, and a new site, designated as "TCE plume," was added. For clarity in this report, CAFB has been subdivided into five geographic sectors, each sector containing between one and six investigation sites. Table S-1 lists the 16 investigation sites by sector. Approximate locations of the Phase II investigation sites are shown in Figure S-1.

A preperformance meeting including representatives of CAFB, OEHL, and WESTON was held at CAFB on 10 and 11 October 1984. Field work was begun on 23 October 1984 and completed on 12 April 1985. The field work included the following elements:

- Drilling and installation of 27 monitor wells in the shallow aquifer and 11 very shallow monitor wells (referred to as "lysimeters") above hardpan.



Table S-1

## Site Organization for Phase II Investigation

Sector Name	Investigation Site Number	Investigation Site Name	Potential Source Site Name
Main Base Sector	1	TCE Plume	TCE Plume
	2	Discharge Area 8	Discharge Area 8 (DA-8)
	3	Discharge Area 5	Discharge Area 5 (DA-5)
	4	Discharge Area 7	Discharge Area 7 (DA-7)
	5	Discharge Area 3	Discharge Area 3 (DA-3)
	6	Discharge Area 6	Discharge Area 6 (DA-6)
South Sector	7	South Landfill Zone (SLFZ)	Landfill 1 (LF-1) Landfill 2 (LF-2) Discharge Area 1 (DA-1) Disposal Pit 1 (DP-1) Disposal Pit 2 (DP-2) Disposal Pit 3 (DP-3) Disposal Pit 4 (DP-4)
	8	Fire-Training Area 1	Fire-Training Area 1 (FT-1)
	9	Landfill 3	Landfill 3 (LF-3)
	10	North Landfill Zone (NLFZ)	Landfill 5 (LF-5) Disposal Pit 7 (DP-7) Disposal Pit 8 (DP-8) Disposal Pit 9 (DP-9)
	11	West Landfill Zone (WLFZ)	Landfill 4 (LF-4) Disposal Pit 5 (DP-5) Disposal Pit 6 (DP-6) Fire-Training Area 2 (FT-2)
	12	PCB Spills 1 to 3	PCB Spills 1 to 3 (PCB)
West Flight-line Sector	13	Fuel Spills 1 to 4	Fuel Spills 1 to 4 (FS1-4)
	14	Discharge Area 2	Discharge Area 2 (DA-2)
	15	Discharge Area 4	Discharge Area 4 (DA-4)
	16	Fire-Training Area 3	Fire-Training Area 3 (FT-3)

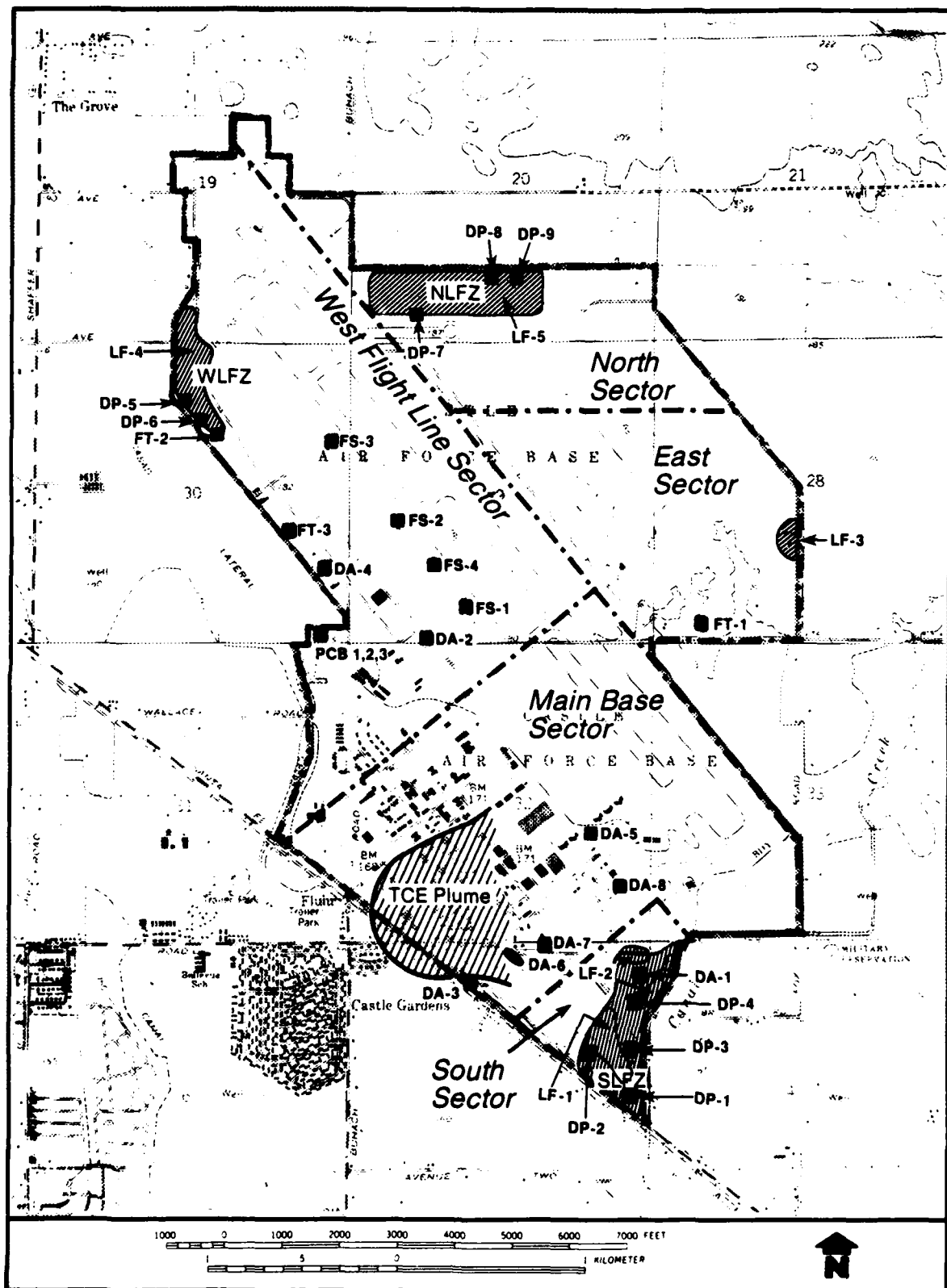


FIGURE S-1 LOCATION OF PHASE II INVESTIGATION SITES AND GEOGRAPHIC SECTORS AT CASTLE AFB



- Collection of soil and sediment samples from three surface sites and three ditch locations.
- Surveying of well casing and water level elevations in all new and existing wells.
- Surface geophysical surveys at 3 sites.
- Two rounds of water quality sampling, including 9 surface water stations, 35 new and existing monitor wells, and 9 Base production wells.
- Pilot test operations at Base production well 3 to evaluate the hypothesis of down-casing leakage between aquifers.

Analytes sampled in soil and groundwater included volatile organic compounds (VOA), total organic carbon (TOC), total organic halogens (TOX), oil and grease, phenols, nitrate, and selected metals, and pesticides and herbicides.

#### MAJOR FINDINGS

##### Hydrogeologic Conditions

The following are general conclusions concerning the regional geologic and hydrogeologic setting at CAFB:

- Three separate producing aquifers can be distinguished in the subsurface below CAFB. The deepest, comprising the upper portion of the Mehrten Formation, occurs approximately below a depth of 800 feet. A confined aquifer, tapped by the Main Base and family housing production wells, occurs between depths of 260 and 300 feet. The new production well (drilled and installed in 1984) draws water from both the deep and confined aquifer. The shallow aquifer consists of a wedge of coarse sands and gravel that appears to thicken and increase in permeability westward beneath the Base. In the Main Base Sector, the shallow and confined aquifers are separated by approximately 150 feet of predominantly clayey sediments and there is a downward hydraulic gradient (on the order of 0.01). The degree of separation or connection between the two aquifers in off-Base areas to the west and southwest is unknown.

- The shallow aquifer is locally overlain by clay lenses which may support perched groundwater; the presence of perched groundwater could not be confirmed by use of mud rotary drilling techniques. The shallow aquifer is considered semiconfined.
- Although hardpan is frequently encountered in shallow soils, hardpan zones do not appear to be laterally continuous, or to provide effective barriers to vertical infiltration. Perched saturated zones were not encountered in the lysimeters finished on top of hardpan.
- Groundwater flow direction in the shallow aquifer beneath CAFB converges toward a northeast-southwest trending trough and exits the area of the Base primarily across the southwestern boundary in the Main Base Sector. Thus, groundwater flow directions in the North and West Flightline Sectors are reversed from the presumed flow direction used in monitor well placement in Stage 1, and additional monitor wells are needed to complete the confirmation stage investigation in those sectors. The only area in which groundwater flow direction was observed to be directly affected by pumping was in the WLFZ, where flow directions were affected by pumping from an off-Base irrigation well.

## Soil and Water Quality

The following are general conclusions concerning soil and water quality data collected at CAFB in the course of this investigation:

- Based on sampling and analysis results, it is concluded that the soils and sediments have not been significantly impacted by the sites sampled at CAFB, although some residual and relatively immobile petroleum byproducts may be present at DA-1 and DA-3. These products may continue to accumulate under current disposal practices at these sites unless these practices are curtailed.

- Of the analytes sampled in surface water from nine staff gage stations in drainage ditches in the Main Base and South Sectors, only pH consistently exceeded the Federal water quality standard of 8.5, at three stations in the west ditch paralleling Santa Fe Boulevard. This has been related to quantities of either detergent solutions or sodium bicarbonate reaching this ditch from DA-3. Traces of VOA compounds and pesticides and herbicides found in both sampling rounds indicate that miscellaneous other discharges may be affecting the ditches, but no significant impact was observed from direct runoff or seepage of sewage effluent sprayed in the LF-1 area. Traces of TCE detected at two surface water sampling stations downstream from DA-8 may be related to seepage from the old TCE overflow pipe in the bank of the ditch; four buried segments of pipe were identified from geophysical surveys between Building 1550 and the ditch, one of which may correspond to the TCE source pipe.
  
- Nitrate concentrations in the shallow aquifer (actually measured as total nitrate and nitrite as nitrate) were found to exceed the Federal drinking water standard of 45 mg/L in the Main Base Sector and in the area of three landfills: SLFZ, NLFZ, AND WLFZ. Due to the location of CAFB in a predominantly agricultural region that is criss-crossed by irrigation supply and drainage canals, levels of nitrate up to 30 mg/L in groundwater are thought to represent normal background levels in the shallow aquifer. The highest nitrate concentrations, downgradient of LF-1 in the SLFZ (ranging up to 74 mg/L), correspond closely to elevated levels of specific conductance, and are thought to have been contributed from landfill leachate, spray effluent, or a combination of the two.
  
- The only other analyte which was found to exceed Federal or State-regulated water quality standards on a widespread basis in the shallow aquifer was TCE. Maximum measured concentrations of TCE were over 0.250 mg/L, or 50 times the California DHS action level of 0.005 mg/L. The TCE contour map in Figure 4-18 illustrates a plume of TCE contamination originating in the Main Base Sector and moving off-Base across the western boundary in the vicinity of the Main Gate. Although the source of the TCE contamination was not positively identified, further investigation at both DA-8 and an old shop building is indicated based on the shape of the plume and current information on groundwater flow direction.

- Samples from Main Base production wells PW-1, PW-2, PW-3, and PW-4 exhibited TCE concentrations ranging up to 0.044 mg/L in PW-3. Evidence from the PW-3 pilot test investigations as well as the existence of a downward vertical gradient in the vicinity of PW-3 tend to support the hypothesis of down-casing leakage between the shallow and confined aquifers. Results of a 4-week pumping test at the end of well reconstruction performed on PW-3 indicated that long-term pumpage from PW-3 would exhibit a sustained TCE concentration averaging 0.010 mg/L. The hypothesis of localized contamination in the confined aquifer only in the immediate vicinity of the Main Base production wells could not be confirmed on the basis of a measured TCE concentration of 0.044 mg/L under static conditions after the pilot test, which corresponds closely to pre-pilot test conditions. Further investigation will be required to evaluate the magnitude of contamination in this aquifer. This is particularly important because after February 1985, the new production well became the principal Main Base supply well. This well is open to both the confined and deep aquifers, and provides a new driving force for contamination to spread in the confined aquifer.

## Site-Specific Conclusions

As a conclusion to the investigation, each of the sites investigated can be categorized according to whether it requires no further action (Category I), requires further investigation (Category II), or is ready for remedial action (Category III). Category II can be further subdivided to distinguish among the different types of investigation alternatives to be considered for each site. The following definitions have been used in the classification of investigation sites at CAFB:

- Category I applies to sites where no further action (including remedial action) is required because sufficient data exist to rule out unacceptable health or environmental risks resulting from the site.
- Category II applies to sites which have confirmed contamination potentially representing unacceptable environmental or health hazards, and require further investigation.



- Category III applies to sites where remedial action is required and all necessary data to support an analysis of remedial alternatives have been gathered. These sites are considered ready for IRP Phase IV action.

Site-by-site conclusions are summarized in Table S-2.

#### RECOMMENDATIONS

Following are recommendations for implementation of the alternatives for further investigation on a site-by-site basis. The site-by-site recommendations are preceded by some general recommendations concerning monitoring of drinking water supplies at CAFB and handling and disposal of hazardous substances, as well as further monitoring programs associated with the IRP.

#### General Recommendations

The following general recommendations are made:

- It is recommended that all discharge of wash-waters and nonaqueous substances directly to soils or to the ditches be curtailed, and that these solutions be routed to the industrial sewers instead.
- Base supply wells are potentially threatened by contamination in the confined aquifer, especially since containment is no longer provided by pumping from the old Main Base production wells. In addition, traces of VOA compounds have been detected in PW-5, PW-6, and PW-11 in the East Sector. For these reasons, it is recommended that all drinking water supply wells be sampled routinely for analysis of the 32 VOA compounds on the U.S. EPA priority pollutant list.



Table S-2

Summary of Site-Specific Conclusions, Castle Air Force Base IRP Phase II,  
Stage 1 Investigation

Sector	Investigation Site	Investigation Category	Rationale	Supporting Subsections of Report
Main Base Sector	1. TCE Plume	II	Confirmed TCE contamination in shallow aquifer migrating off-Base and requiring remedial action, due to threatened private and public water supplies; further investigation required to confirm source and estimate extent of contamination in confined aquifer.	4.3 4.6.2.1
	2. DA-8	II	Confirmed TCE contamination in shallow aquifer; further investigation required to confirm presence and quality of perched groundwater above shallow clay. Possible segments of discharge pipe located by geophysical surveys.	4.2.4.1 4.4.1 4.5.2.1 4.6.2.1 4.7
	3. DA-5	I	No evidence of contamination; no further investigation required except in conjunction with DA-8 and FITS area as a whole.	
	4. DA-7	I	No evidence of contamination with pesticides or herbicides in soil at DA-7, or anywhere in groundwater.	4.5.1.1
	5. DA-3	II	Confirmed contamination with oily substance in TW-17, visual evidence of dry-well disposal; confirmed elevated oil and grease in ditch sediments.	4.5.2.3 4.6.2.1 4.7

Table S-2  
(continued)

Sector	Investigation Site	Investigation Category	Rationale	Supporting Subsections of Report
Main Base Sector (continued)	6. DA-6	I	No evidence of groundwater contamination directly associated with this site in TW-13 or other wells.	4.6.2.1
South Sector	7. SLFZ-general	III	Confirmed effluent application. Confirmed groundwater contamination with inorganics and trace organics. No unacceptable health or environmental risks at current levels.	4.6.2.2 4.7
	7a. SLFZ - DA-1	I	Confirmed elevated oil and grease levels in soils, but no VOA's. Groundwater is adequately monitored by existing SLFZ network.	4.5.1.2
	7b. SLFZ - DP-3	I	Probable fill and possible buried drums detected in geophysical surveys; however, groundwater is adequately monitored by existing SLFZ network.	4.4.2
East Sector	8. FT-1	II	Confirmed trace organic contamination in shallow groundwater, occasional TCE in excess of CDHS action levels.	4.6.2.3
	9. LF-3	II	Unconfirmed contamination with TCE in one round.	4.6.2.3

Table S-2  
(continued)

Sector	Investigation Site	Investigation Category	Rationale	Supporting Subsections of Report
North Sector	10. NLF2	II	Evidence of crushed and buried drums from visual and verbal reports; probable buried drums in trenches detected from geophysical surveys; some preliminary evidence of shallow groundwater contamination with inorganics, but monitor wells not located to sample down-gradient groundwater.	4.2.4.4 4.4.3 4.6.2.4
	11. WLF2	II	Confirmed impact on shallow groundwater from contamination with inorganics, trace organics, proximity to off-Base pumping well. Needs closer downgradient wells.	4.5 4.6.2.5
West Flightline Sector	12. PCB 1-3	Not Investigated	Ongoing Base-initiated clean up.	3.2.2
	13. FS1-4	II	Monitor well not located to sample downgradient groundwater.	4.2.4.5 4.2.6.5
	14. DA-2	II	Monitor well not located to sample downgradient groundwater. Some preliminary evidence of contamination with VOA's.	4.2.4.5 4.6.2.5
	15. DA-4	II	No evidence of contamination in soil. Monitor well recommended due to presence of miscellaneous VOA's in shallow groundwater in the West Flightline Sector from upgradient sources.	4.5.1.3 4.2.6.5
	16. FT-3	II	Monitor well not located to sample downgradient groundwater.	4.2.4.5 4.6.2.5



### SITE-SPECIFIC RECOMMENDATIONS

Site-specific recommendations for further field investigations at 12 sites have been summarized in Table S-3.

The TCE plume is the site of most immediate concern at CAFB because it poses the most direct potential threat to drinking water supplies. Contamination associated with the TCE plume in the shallow aquifer can be considered to be fairly well-defined within the Base boundaries on the basis of current information. Due to evidence for off-Base migration of the plume, it is recommended that an analysis of remedial alternatives be initiated along with further site investigations to develop and evaluate recommendations for containment and cleanup in the shallow aquifer, and in the deep aquifer if necessary.

Questions remain concerning three critical factors: 1) the source of contamination (where is it located and is it a currently active source?), 2) the degree of communication between the shallow and the confined aquifers in off-Base areas, and 3) the extent of contamination in the confined aquifer. The following specific recommendations for further investigation have been developed to address those questions:

- Conduct additional record search and interviews of Base personnel to identify additional potential sources of TCE in the Main Base area.
- Conduct a thorough review of all available documentation on well logs and geology reports for wells down-gradient of the Base. This review will serve to evaluate the degree of communication between aquifers occurring either naturally, through "windows" in the confining clay layers, or artificially, through wells perforated or gravel-packed in more than one aquifer. This study, to be performed in cooperation with state and local agencies (County Health Department, City of Atwater, Merced Irrigation District), should include a field check of each well to sound it and collect a water level measurement, and sampling of selected wells for VOA compounds.

Table S-3

Summary of Investigation Recommendations

Sector	Site	Existing Monitor Wells		Recommended New Monitor Wells		Recommended Soil Borings/ Perched Aquifer Wells		Recommended Surface Water Sampling Points	Recommended Analytes in Water	Recommended Additional Field Activities
		Confined Aquifer	Shallow Aquifer	Confined Aquifer	Shallow Aquifer					
Main Base Sector	TCE plume	PW-1, PW-2, PW-3, PW-4	MW-210, MW-220, TW-13, TW-14, TW-15, TW-16, TW-17, TW-18	6	12	12	---	---	VOA	Soil gas testing
		---	MW-290, MW-300, MW-310	---	---	6	2	---	VOA	Soil gas testing
		---	TW-17	---	3	3	---	---	VOA, petroleum hydrocarbon ID	Soil gas testing
		---	MW-320, MW-330, MW-340	---	2	4	---	---	VOA	Soil gas testing
East Sector	Fire-Training Area 1	---	MW-460, MW-470	---	---	---	---	---	VOA	---
	Landfill 3	---	MW-350, MW-360, MW-370, MW-380	---	2	---	2	---	VOA, nitrate, chloride, sulfate, arsenic, boron, metals, pesticides and herbicides	---
North Sector	North Landfill Zone	---		---						

Table S-3  
(continued)

Sector	Site	Existing Monitor Wells		Recommended New Monitor Wells		Recommended Soil Borings/ Perched Aquifer Wells	Recommended Surface Water Sampling Points	Recommended Analytes in Water	Recommended Additional Field Activities
		Confined Aquifer	Shallow Aquifer	Confined Aquifer	Shallow Aquifer				
West Flight-line Sector	West Landfill Zone	---	MW-390, MW-400, MW-410, MW-420	---	2	3	---	VOA, nitrate, chloride, sulfate, arsenic, boron	Soil gas testing
		---	MW-430	---	1	1	---	VOA, petroleum hydrocarbon ID	Soil gas testing
		---	MW-440	---	1	1	---	VOA	Soil gas testing
	Fire-Training Area 3	---	---	---	1	1	---	VOA	Soil gas testing
---		MW-450	---	1	1	---	VOA	Soil gas testing	
Total Recommended New Sampling Points:				6	25	32	4		

- Test shallow soil gas for the presence of halogenated VOA compounds in up to 75 locations on-Base in the Main Base Sector and off-Base in the area of presumed downgradient migration of TCE in groundwater. Use soil gas testing for the purposes of both locating sources of TCE in soil and reaching the downgradient migration in groundwater.
- Install up to 12 additional wells in the shallow aquifer on- and off-Base to confirm the results of the soil gas testing, to further define the plume in that area, and to ascertain the degree of contamination in the shallow aquifer immediately overlying the new PW.
- Install up to six monitor wells in the confined aquifer. These wells will have to be specially constructed by grouting a casing into the confining clay separating the shallow and confined aquifers, and drilling through it into the confined aquifer, so as to ensure that the new monitor wells do not act as conduits between aquifers.

#### SITE-SPECIFIC REMEDIAL INVESTIGATIONS

One site, the SLFZ, has been classified in Category III requiring Phase IV action. IRP Phase IV actions include site remediation actions and long-term monitoring actions.

Based on this investigation, the South Landfill Zone has been shown to have affected shallow groundwater quality by contributing conductive (i.e., inorganic) constituents, primarily from the area of LF-1. None of the parameters identified, however, were found to exceed Federal or state water quality standards. Although the existing monitoring network is adequate to monitor upgradient and downgradient groundwater, the analytical protocol should be designed to monitor constituents characteristic of landfill leachate (e.g., boron), as well as additional compounds for which water quality standards exist (e.g., chloride, sulfate, arsenic) to confirm that no health or environmental hazards are associated with leachate generation or continued spraying of sewage effluent on the fill area.

It is recommended that a routine monitoring program be initiated and be continued for at least one year after cessation of effluent application. No other Phase IV actions are recommended for the site based on currently available data.



## SECTION 1

### INTRODUCTION

#### 1.1 INSTALLATION RESTORATION PROGRAM

In 1976 the Department of Defense (DOD) devised a comprehensive Installation Restoration Program (IRP). The purpose of the IRP is to assess the potential migration and control the actual migration of environmental contamination that may have resulted from past operations and disposal practices on DOD facilities. In response to the Resource Conservation and Recovery Act of 1976 (RCRA) and in anticipation of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or "Superfund"), the DOD issued a Defense Environmental Quality Program Policy Memorandum (DEQPPM) dated June 1980 (DEQPPM 80-6), requiring identification of past hazardous waste disposal sites on DOD agency installations. The U.S. Air Force implemented DEQPPM 80-6 by message in December 1980. The program was reviewed by DEQPPM 81-5 (December 1981) which reissued and amplified all previous directives and memoranda on the IRP. The Air Force implemented DEQPPM 81-5 by message on 21 January 1982. The Installation Restoration Program has been developed as a four-phase program as follows:

- Phase I - Problem Identification/Records Search
- Phase II - Problem Confirmation and Quantification
- Phase III - Technology Base Development
- Phase IV - Corrective Action

Only the Phase II, Stage 1, Problem Confirmation portion of the IRP effort at Castle Air Force Base (CAFB) was included in the effort described in this report. Definitions of the acronyms, nomenclature, and units of measurement used in this report are included in Appendix A.

#### 1.2 PROGRAM HISTORY AT CASTLE AIR FORCE BASE

The Phase I, Problem Identification/Records Search for Castle Air Force Base was accomplished by Engineering Sciences, Inc. (ESI). Their site visit was made in July 1983, and their Final Report was dated October 1983.



Roy F. Weston, Inc. (WESTON) had been retained by the United States Air Force Occupational and Environmental Health Laboratory (OEHL) under Contract Number F33165-80-D-4006 to provide general engineering, hydrogeological, and analytical services on a task order basis. In response to the findings contained in the ESI Phase I Final Report for CAFB, the OEHL issued Task Order 0032 to WESTON, directing that a presurvey be conducted at CAFB. The purpose of this presurvey was to obtain sufficient information to develop a work scope and cost estimate for the conduct of a full Phase II, Stage 1, Problem Confirmation Study at CAFB. The presurvey site inspection was conducted at CAFB by two WESTON personnel and a representative of OEHL on 28 February 1984, and the Presurvey Report was submitted in March 1984.

In September 1984 WESTON was issued a new contract (Contract Number F33615-84-D-4400) by OEHL. Following modifications in the scope of work proposed in the Presurvey Report, Task Order 0002 under the new contract was issued. This task order authorized a Phase II, Stage 1, Problem Confirmation Study at 21 of the 26 potential source sites at CAFB identified in the Phase I Final Report (ESI, 1983). A copy of the formal task order authorizing this work is included as Appendix B in this report.

A preperformance meeting including representatives of CAFB, OEHL, and WESTON was held at CAFB on 10 and 11 October 1984. Field work was begun on 23 October 1984 and completed on 12 April 1985. This report summarizes methods used, findings, and recommendations for additional work based on the results of the Phase II, Stage 1, Problem Confirmation Study.

### 1.3 BASE PROFILE

CAFB is located in the northwest half of Merced County, in the San Joaquin Valley near the geographic center of the State of California (Figure 1-1). The host organization at CAFB is the 93rd Bombardment Wing. Aircraft regularly maintained at CAFB include B-52 stratofortresses (G and H Series), KC-135 strato-tankers, T-33 training fighters, and F-15 fighters.

Generation of hazardous wastes at CAFB has been associated with industrial operations, fuels management, fire protection training, and pesticide utilization (ESI, 1983). Historically, on-Base disposal methods have included primarily landfilling, disposal in pits, and burning in fire protection training areas. This section includes a description of the current Base organization and a review of Base history, particularly as it relates to the development of disposal areas and industrial areas where hazardous materials would have been handled.

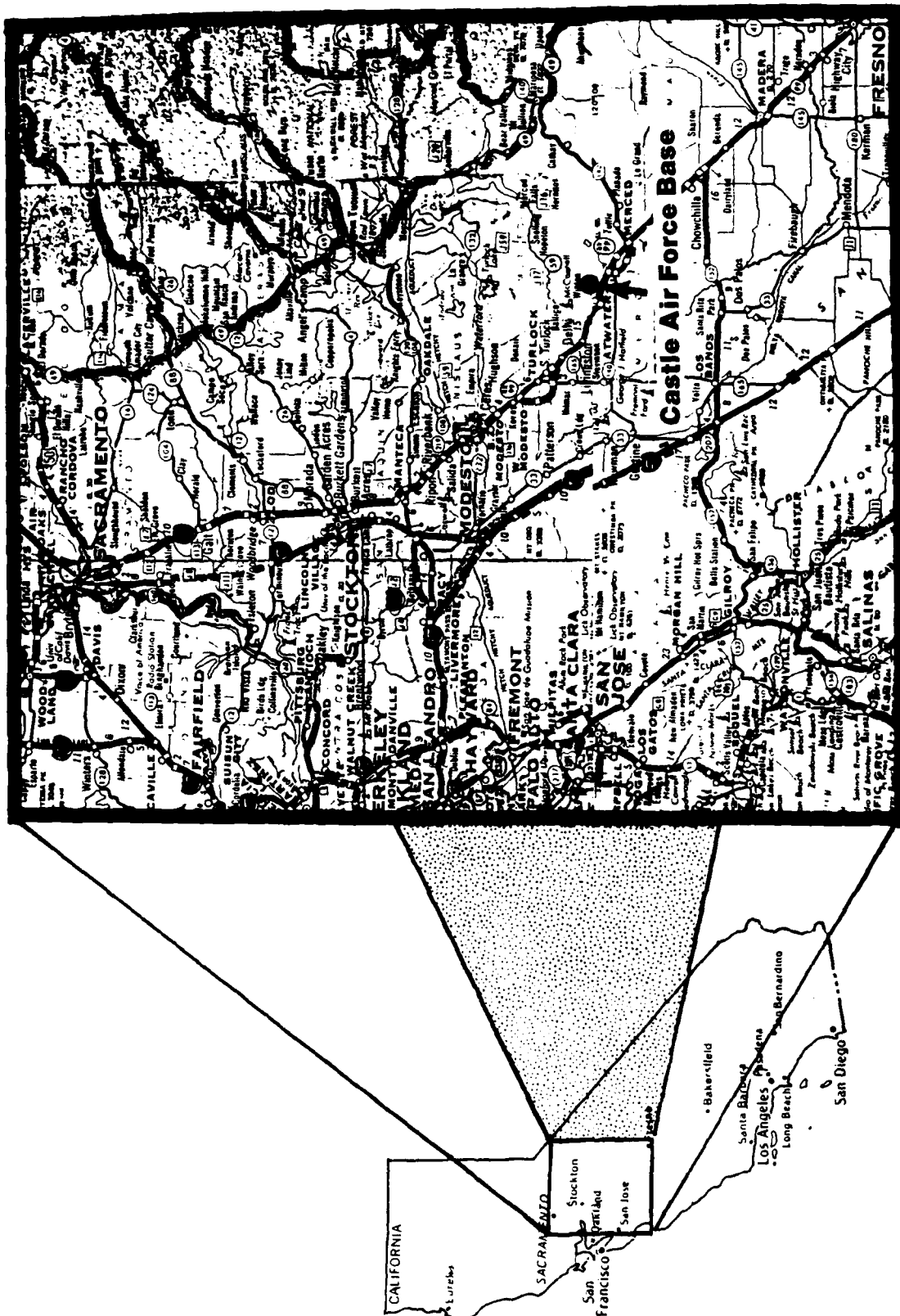


FIGURE 1-1 INDEX MAP FOR CASTLE AIR FORCE BASE



### 1.3.1 Current Organization and Mission

Currently, the host organization at CAFB is the 93rd Bombardment Wing. The primary mission of the 93rd is to develop and maintain a combat-ready force capable of long-range bombardment operations for the Strategic Air Command (SAC). Its second mission is to train all SAC combat crews for B-52 stratofortresses and KC-135 stratotankers. The 93rd is also responsible for operating CAFB and providing support to the tenant organizations. Following is a list of the major Base tenant organizations:

- 84th Fighter Interceptor Training Squadron
- 318th Fighter Interceptor Squadron, Det. 1
- SAC Management Engineering Team
- 2035th Communications Squadron
- Det. 1, 4200 Test and Evaluation Squadron
- Det. 412, Air Force Audit Agency
- Field Training Det. 514
- Det. 2, 9th Weather Squadron
- Det. 1, 323 Flying Training Wing

### 1.3.2 History of Industrial Development and Waste Disposal at CAFB

CAFB was initially activated as an Army Air Base in the second half of 1941. The first military aircraft landed at the Base on 7-8 December 1941, in the wake of the Pearl Harbor attack, although no runways or flying facilities had been completed. Construction of the first control tower and two hangars (T-47 and T-51) was begun in December 1941. The main shop building, T-52, was built shortly thereafter, in early 1942.

The primary mission of the Base during the early 1940's was air crew training. In 1945, all flying personnel and aircraft were transferred out of CAFB. In February 1946, the 59th Weather Reconnaissance Squadron was assigned to CAFB, and conducted weather reconnaissance operations with B-29, B-17, and C-54 aircraft. The Strategic Air Command (SAC) assumed responsibility for the Base in April 1946. In July 1947, SAC activated the 93rd Bombardment Wing. The 93rd was assigned B-29's in early 1947, B-50's in June 1949, and B-47's in 1949. The first B-52's arrived at CAFB in 1955, and shortly thereafter the Wing began training B-52 crews for SAC. In 1957, the program was increased to include training of tanker crews with the arrival on Base of the first KC-135 stratotankers.

# WESTON

Fighter planes were first assigned to CAFB in March 1956, after activation of the 456th Fighter Interceptor Squadron (FIS). The first fighters were F-86D's, followed by F-102's. In May 1973, the 84th FIS, which later became the 84th Fighter Interceptor Training Squadron (FITS), was assigned to CAFB, followed by the 318th FIS (Detachment 1). The aircraft assigned to the 84th FITS are T-33's. The first F-15's were assigned to the 318th in late 1983.

Construction of Base facilities closely paralleled increases in the size of the Base mission and the number of tenant organizations. The original runway, corresponding approximately to the center portion of the existing runway, was only 7,000 feet long. Southwest of the runway was a 1,500-foot by 3,500-foot landing mat in the location of what is now the operational apron, and a 510-foot by 4,200-foot parking apron beneath the current Base Operations parking lot. The principal industrial activities related to aircraft maintenance were originally centered in the hangars (T-47 and T-51) and shop building (T-52) on the southwest side of Apron Avenue.

Paving of the operational apron and extension of the runway began in 1953, and in 1953 or 1954 Base Operations was moved to the existing control tower location. The B-52 hardstands and larger maintenance hangars just southwest of the new operational apron were also built in the early 1950's. In late 1955, an additional operational apron, alert hangar (Building 1550), and other facilities were built for the FIS on the southeast side of the main operational apron. Since that time, industrial activities associated with FIS operations have essentially been confined to Building 1550, and the washrack area and associated small buildings immediately to the west of Building 1550.

Buildings 1253 and 1260 were built in the late 1970's to house some of the shop activities (corrosion control, metals processing, and jet engine intermediate maintenance) of the 93rd Field Maintenance Squadron. Until that time, these shop activities had been housed in the original shop building, T-52, which was demolished in late 1977 or early 1978.



Disposal of solid waste has occurred on Base in five landfills, referred to as LF-1 through LF-5. LF-1, operated from 1940 to 1950, and LF-2, operated from 1951 to 1953, were located in the South Sector of the Base. In the mid to late 1950's, landfills were opened on the eastern perimeter (LF-3, 1954 to 1956) and the western perimeter (LF-4, 1957 to 1970). The last landfill, LF-5, was operated from 1971 to 1977 on the northern perimeter, and still receives hardfill wastes consisting of construction debris and concrete rubble which are disposed of in mounds on the surface.

Nine chemical disposal pits associated with these landfills were identified in the Phase I report. These were generally located on the periphery of a solid waste landfill and operated concurrently with it. They were used for disposal of bulk chemical wastes, primarily solvents, oils, and fuel sludges. No burning was conducted at any of the disposal pits. Since the mid 1970's, waste oils and fuels have been collected for off-Base disposal of petroleum wastes, including some solvents and other wastes comingled with them.

In addition to disposal in pits, incineration of fuels and combustible chemical wastes in fire-training exercises has been practiced as a disposal method at CAFB. Three fire-training areas were identified in the Phase I report: FT-1 (1955 to 1975) near the eastern perimeter and FT-2 (1962 to 1967) and FT-3 (1967 to present) on the western perimeter.

CAFB has operated a sewage treatment plant (STP) for treatment and disposal of wastewaters since at least 1942 (based on aerial photographs). The STP, located in the South Sector of the Base, has incorporated several different processes over its period of operation (ESI, 1983). The basic treatment facility includes two parallel plants, each consisting of a primary clarifier, a trickling filter, and a final clarifier. During the 1940's and early 1950's, the STP effluent was discharged to a series of shallow evaporation ponds occupying approximately 25 acres in the area between the STP and Santa Fe Boulevard. From the 1950's until 1977, the ponds were closed, and treated effluent was discharged directly to Canal Creek off-Base. In approximately 1960 a separate system of oil/water separators and industrial sewers to carry oily wastewaters was installed. Wastewaters from this system were not treated in the STP, but were discharged to a shallow, unlined evaporation pond (DA-6) built from one of the earlier ponds adjacent to and southeast of the STP. In 1977, the State of California ordered the industrial wastewater evaporation pond closed and cessation of discharges to the creek. Since 1977, industrial wastewaters have been held in a temporary storage tank at the STP, comingled with treated sanitary effluent from the STP, and applied as spray irrigation to the area of LF-1 in the South Sector of the Base.



### 1.3.3 Contamination Profile

According to the Phase I report, industrial operations at CAFB have been associated primarily with routine aircraft and vehicle maintenance. Primary chemicals of concern are waste oils and fuels, solvents and cleaners, and minor amounts of paint and plating wastes. Most of the industrial operations have been in existence since the mid 1940's, and expanded industrial activities related to the SAC mission resulted in increased waste generation rates after the mid 1950's. However, the quantities of wastes generated at CAFB are relatively small compared to those produced at Bases with major aircraft maintenance, overhaul, and other industrial missions. Standard procedures for industrial waste disposal in the past have included landfilling, disposal in pits, fire department training, and contractor salvage.

Based on the types of suspected contamination at Castle AFB, a reasonable analytical protocol for screening potential source sites would include volatile organic compounds (generally the most volatile components of fuels and oils) and related screening parameters for organic contamination such as total organic carbon (TOC), total organic halogens (TOX), and oil and grease; phenols, nitrates, metals, pesticides and herbicides should also be included at specific sites where their presence might be suspected.

### 1.4 HISTORY AND DESCRIPTION OF THE PHASE II INVESTIGATION SITES

#### 1.4.1 Report Organization

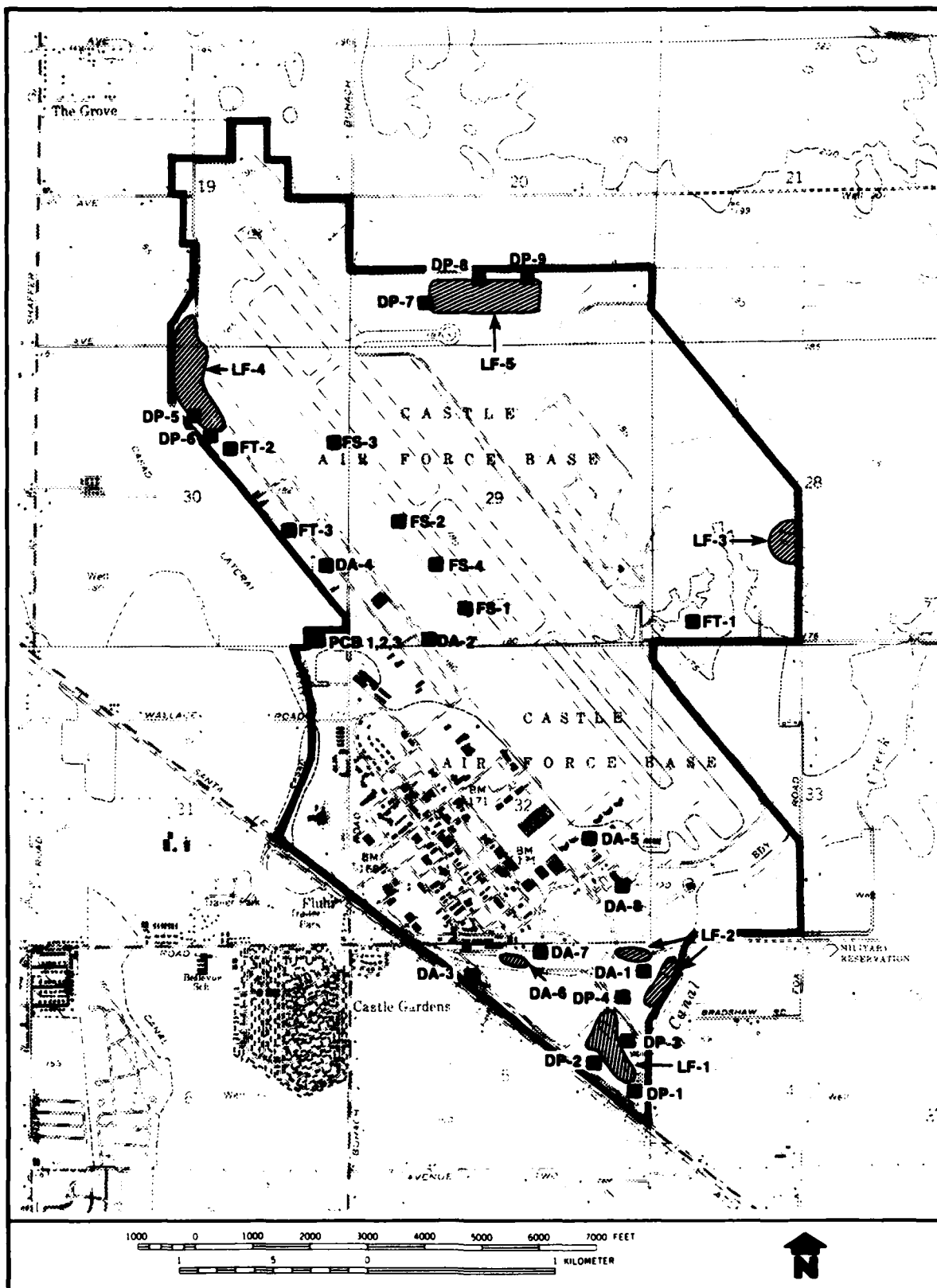
The Phase I report (ESI, 1983) identified 37 sites on CAFB representing potential sources of contamination due to past handling or disposal of potentially hazardous wastes. These included 5 landfills, 8 discharge areas, 9 chemical-disposal pits, 3 fire-training areas, 4 fuel-spill areas, and 8 PCB-spill areas. Many of the disposal pits were adjacent to or incorporated into landfills, and several of the spill areas were so close to each other as to be considered a single source. Therefore, the 37 individual sites were grouped into 26 potential source sites by ESI (1983) and ranked according to the Hazard Assessment Ranking Methodology (HARM) used by the USAF to prioritize sites for investigation. The HARM scores for the 26 potential source sites are summarized in Table 1-1. Of the 26 ranked Phase I sites, five sites (PCB Spills 4 through 8) were removed from further IRP investigation because remedial actions undertaken by the Base were considered to have eliminated all potential sources of contamination from these sites. Locations of the remaining 21 sites are shown in Figure 1-2.

Table 1-1

Summary of HARM Scores for Phase I Sites Identified at CAFB

Rank	Site Name	Receptor Subscore	Waste Character- istics Subscore	Pathways Subscore	Waste Management Factor	Overall Total Score
1	Landfill 1, Chemical Disposal Pits 1, 2, and 3	74	80	93	1.0	82
2	Fire Protection Training Area 1	72	100	56	1.0	76
2	Landfill 5, Chemical Disposal Pits 7, 8, and 9	66	100	63	1.0	76
4	Discharge Area 1	72	72	71	1.0	72
5	Discharge Area 8	73	60	80	1.0	71
6	Fuel Spill 1	65	80	71	0.95	68
7	Discharge Area 4	68	60	71	1.0	66
7	Discharge Area 7	76	60	63	1.0	66
7	Landfill 4, Chemical Disposal Pits 5 and 6	66	70	63	1.0	66
10	Chemical Disposal Pit 4	67	70	56	1.0	64
10	Discharge Area 5	75	45	71	1.0	64
10	Discharge Area 2	67	54	71	1.0	64
10	Fuel Spill 4	65	64	63	1.0	64
10	Discharge Area 3	76	45	71	1.0	64
15	PCB Spills 1, 2, and 3	74	40	71	1.0	62
16	Fuel Spills 2 and 3	65	40	71	1.0	59
17	Fire Protection Training Area 3	67	40	56	1.0	54
18	Discharge Area 6	49	45	63	0.95	50
18	Landfill 2	70	16	63	1.0	50
18	Fire Protection Training Area 2	67	40	42	1.0	50
21	Landfill 3	66	16	63	1.0	48
22	PCB Spill 4	76	60	71	0.1	7
22	PCB Spill 6	76	60	71	1.0	7
24	PCB Spill 5	78	60	56	0.1	6
24	PCB Spill 8	75	40	71	1.0	6
26	PCB Spill 7	39	40	56	1.0	5

Source: ESI, 1983.



**FIGURE 1-2 LOCATION OF POTENTIAL SOURCES OF CONTAMINATION AT CASTLE AFB IDENTIFIED IN PHASE I**  
(SEE TABLE 1-2 FOR EXPLANATION)



For the purposes of problem confirmation investigation, the remaining 21 potential source sites were grouped into 15 investigation sites, and a new site, designated as "TCE plume," was added. Both the proposed work scope in the Presurvey Report and the actual authorized work scope in the task order (Appendix B) addressed the following 16 investigation sites:

- TCE Plume.
- South Landfill Zone - Landfills 1 and 2, Discharge Area 1, Disposal Pits 1, 2, 3, and 4.
- Discharge Area 8.
- Fire-Training Area 1.
- North Landfill Zone - Landfill 5, Disposal Pits 7, 8, and 9.
- West Landfill Zone - Landfill 4, Disposal Pits 5 and 6, Fire Training Area 2.
- PCB Spills 1, 2, and 3.
- Fuel Spills 1, 2, 3, and 4.
- Discharge Area 2.
- Discharge Area 4.
- Discharge Area 5.
- Discharge Area 3.
- Discharge Area 7.
- Discharge Area 6.
- Fire-Training Area 3.
- Landfill 3.

For clarity in this report, CAFB has been subdivided into five geographic sectors, each sector containing between one and six investigation sites. Later sections in this report will be organized on a sector basis. Table 1-2 summarizes the breakdown of the 16 investigation sites by sector. The 21 source sites plus the TCE plume have been broken down into 28 individual potential source sites and have also been listed by sector in Table 1-2. Figure 1-3 shows the geographic breakdown of the Base into sectors and the locations of the 28 potential source sites. The following subsections include a brief history and description of each site based primarily on information obtained from the Phase I report (ESI, 1983), including some incidental information obtained from the review of Base photographs and documents described in a later section of this report, as well as field observation during the course of the Phase II, Stage 1 investigation.

#### 1.4.2 Main Base Sector

Figure 1-4 is a map of the Main Base Sector showing the locations of the Phase II investigation sites. There are six investigation sites in the Main Base Sector, including a TCE plume which was added as a separate site for investigation after the Phase I study.

##### 1.4.2.1 TCE Plume

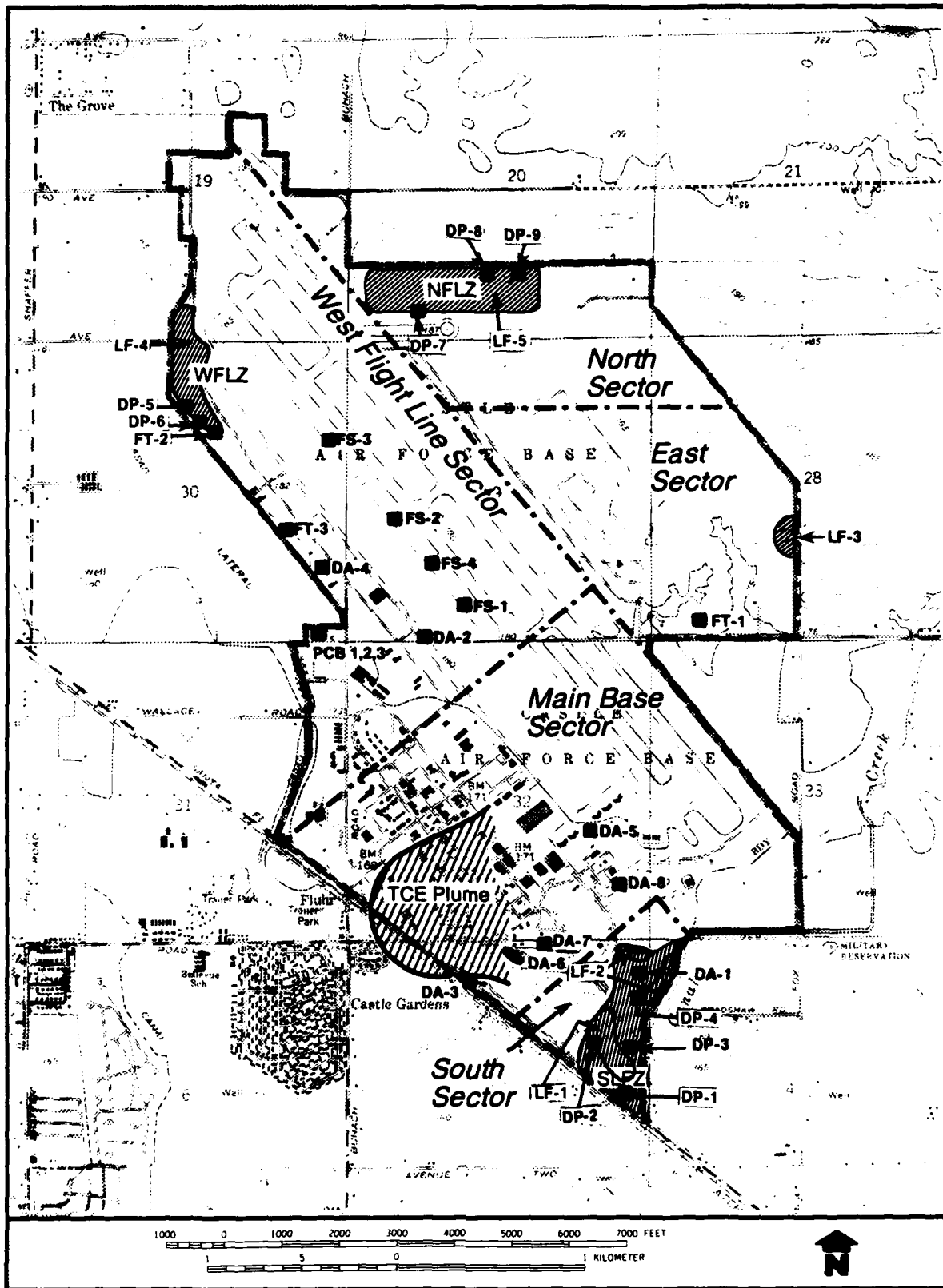
The USAF began sampling Base production wells for organic compounds in March 1978. Further rounds of sampling confirmed that some priority pollutant volatile organic compounds were present in production wells 2, 3, and 4 (see discussion of groundwater quality conditions in Subsection 2.3.4). Of these, trichloroethylene (TCE) appeared most frequently at detectable levels, ranging up to 46 parts per billion (ppb) in PW-3. In November 1981, the Base installed seven test wells in the Main Base and South Sectors to make an initial determination of the extent of TCE contamination present in the shallow aquifer which overlies the main producing zone for the Main Base production wells. TCE was found at detectable levels in six of the seven test wells, ranging from 0.0016 to 0.136 parts per million (ppm), with the highest concentrations found in TW-16 east of the production wells. TCE was found at only trace concentrations or not at all in TW-12, located on the west side of LF-1 in the South Sector. Production and test well locations are shown in Figures 1-4 and 1-5.



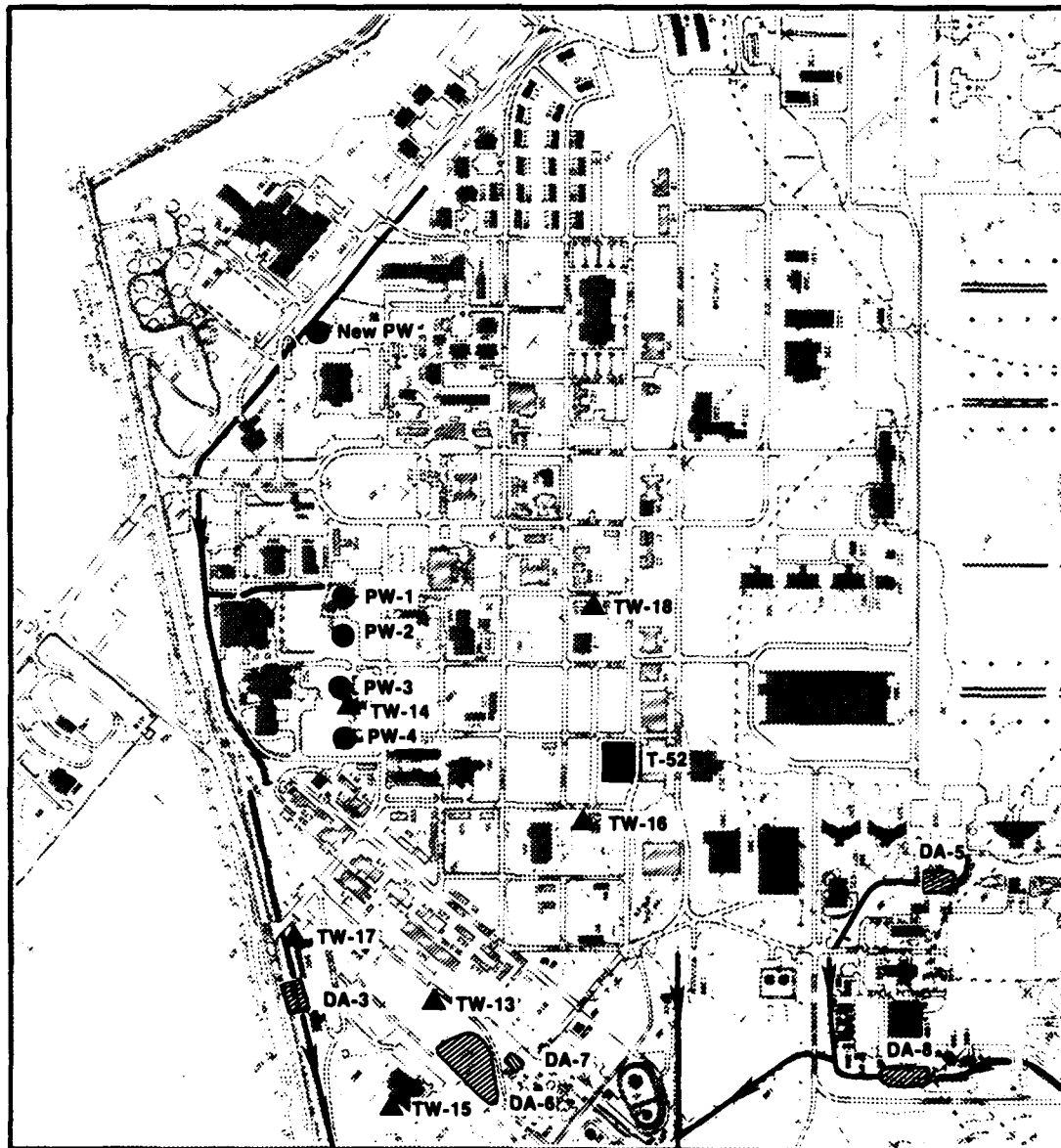
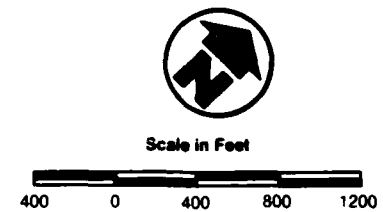
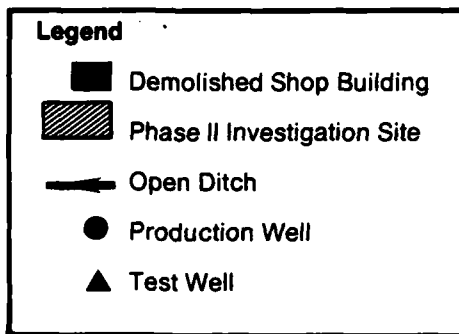
Table 1-2

## Site Organization for Phase II Investigation

Sector Name	Investigation Site Number	Investigation Site Name	Potential Source Site Name
Main Base Sector	1	TCE Plume	TCE Plume
	2	Discharge Area 8	Discharge Area 8 (DA-8)
	3	Discharge Area 5	Discharge Area 5 (DA-5)
	4	Discharge Area 7	Discharge Area 7 (DA-7)
	5	Discharge Area 3	Discharge Area 3 (DA-3)
	6	Discharge Area 6	Discharge Area 6 (DA-6)
South Sector	7	South Landfill Zone (SLFZ)	Landfill 1 (LF-1)
			Landfill 2 (LF-2)
			Discharge Area 1 (DA-1)
			Disposal Pit 1 (DP-1)
			Disposal Pit 2 (DP-2)
			Disposal Pit 3 (DP-3)
East Sector	8	Fire-Training Area 1	Fire-Training Area 1 (FT-1)
	9	Landfill 3	Landfill 3 (LF-3)
North Sector	10	North Landfill Zone (NLFZ)	Landfill 5 (LF-5)
			Disposal Pit 7 (DP-7)
			Disposal Pit 8 (DP-8)
			Disposal Pit 9 (DP-9)
West Flight-line Sector	11	West Landfill Zone (WLFZ)	Landfill 4 (LF-4)
			Disposal Pit 5 (DP-5)
			Disposal Pit 6 (DP-6)
			Fire-Training Area 2 (FT-2)
	12	PCB Spills 1 to 3	PCB Spills 1 to 3 (PCB)
	13	Fuel Spills 1 to 4	Fuel Spills 1 to 4 (FS1-4)
	14	Discharge Area 2	Discharge Area 2 (DA-2)
	15	Discharge Area 4	Discharge Area 4 (DA-4)
	16	Fire-Training Area 3	Fire-Training Area 3 (FT-3)



**FIGURE 1-3 LOCATION OF PHASE II INVESTIGATION SITES AND GEOGRAPHIC SECTORS AT CASTLE AFB**  
(SEE TABLE 1-2 FOR EXPLANATION)



**FIGURE 1-4 MAIN BASE SECTOR MAP**

The test wells are screened in a relatively shallow sand and gravel aquifer, underlain in the Main Base Sector by 140 to 180 feet of clay and sandy clay, with some thin sand interbeds. Production wells 1, 2, 3, and 4 were installed in 1939 by driving 14-inch casings past the upper shallow aquifer, through the clays, and into a water-bearing sandy formation at 285 to 300 feet below ground surface. The casing bottoms were left open, and the wells were developed first by bailing, then by pumping large volumes of sand from the bottom to open up a cavity in the lower sand formation. It has been reported that all four wells have continued to pump sand, especially when they are first started up, since they were installed 45 years ago. In the Phase I report, ESI (1983) speculated that the annulus around the well casing might have been disturbed during well installation by the cable-tool bailing and driving method, leaving a potentially permeable conduit down the outside of the casing between the shallow aquifer and the main producing zone. Extensive pumping from these wells over a 45-year period would have enhanced this conduit, enabling a significant volume of water to move from the shallow aquifer to the production zone. It was concluded that this was the most likely pathway for contaminant migration to the producing zone, with the production wells themselves providing both the conduit and the driving force downward. Therefore, groundwater contamination with TCE in the deeper aquifer was thought to be confined to the immediate vicinity of the production wells.

As a corollary to this, it can be assumed that the main body of TCE-contaminated groundwater is confined primarily to the shallow aquifer, and can be traced to one or several surface sources of TCE discharge. Therefore, during the Phase I study, special attention was paid to operations involving the handling and disposal of TCE. At the time of the Phase I study, the configuration of the plume and the available data on TCE concentrations indicated that the source was most likely to have been located in the Main Base Sector, in the industrial shop or operational apron areas of the 93rd OMS or the 84th FITS. ESI (1983) concluded that the most likely source was DA-8, discussed in the following subsection.



#### 1.4.2.2 Discharge Area 8 (DA-8)

Discharge Area 8 corresponds to a section of the drainage ditch southeast of Building 1550. Building 1550 is the old "Alert Hangar," and has contained several industrial shops related to fighter aircraft maintenance and support. According to ESI (1983), TCE was confirmed to have been used between 1973 and 1976, and may have been used earlier. Prior to 1976, it was used in an ultrasonic cleaner in Building 1550, and an overflow line from the cleaner discharged TCE directly to a ditch behind Building 1550 that was reportedly dry most of the year. According to ESI (1983), 5 gallons per month of TCE were discharged to the ditch for several years. The current ditch, which was moved to a location farther away from Building 1550 in 1960, runs wet most of the year, and there is no evidence of a discharge pipe along the ditch bank nearest Building 1550.

#### 1.4.2.3 Discharge Area 5 (DA-5)

Discharge Area 5 corresponds to a section of the drainage ditch adjacent to the main aircraft washrack, which has received runoff from that washrack. The washrack has been used since the mid 1950's, and was designed to drain into an oil/water separator. It is reported that aircraft cleaning agents (detergents, PD-680, and volatile organic solvents in earlier years) and other shop solvent wastes have been washed into the oil/water separator. The oil/water separator was designed to separate the oil and floating solvents off of the washwater, and pump them into an elevated storage tank adjacent to the washrack. Water from the oil separator is directed to the STP. It has been reported that in the past, drainage from the wash-racks bypassed the oil/water separator, and ran off directly into the drainage ditch. In addition, water separated in the oil-solvent storage tank was drawn off the bottom and allowed to flow into the drainage ditch. There is no estimate available on the volume of oils and solvents which may have been discharged to DA-5 in this manner.

#### 1.4.2.4 Discharge Area 7 (DA-7)

Discharge Area 7 is located in the entomology yard, a fenced-off area adjacent to the Water and Wastewater Department office (Building 906) at the STP. According to ESI (1983), the site received rinse water from cleaning pesticide containers and equipment from the late 1940's until 1979. In 1979, the Base constructed a pit approximately 5 feet deep and 10 feet wide, with a plastic membrane liner. Pesticide rinse waters were directed to this pit and allowed to evaporate. It is reported that the pit was built partially above-ground. Sometime between 1983 and October 1984 it was removed, and the area covered with 0.5 to 1 foot of clean fill. Some handling of pesticides still occurs at the site.

#### 1.4.2.5 Discharge Area 3 (DA-3)

Discharge Area 3 corresponds to a portion of the perimeter drainage ditch running along Santa Fe Boulevard which receives runoff from the Civil Engineering Yard washrack (Building 850). The washrack has reportedly been in use from the early 1950's to the present. Runoff from the washrack carries detergents, cleaning solvents, oils, and possibly low concentrations of herbicides generated in rinsing spray application equipment (ESI, 1983). In addition, it has been reported that battery acid "neutralized" with excess quantities of sodium bicarbonate and antifreeze have occasionally been discharged at DA-3, but that this practice was stopped in July 1985 (Base records, 1985). Although not reported by ESI, the runoff from the washrack was observed to flow into two sumps consisting of vertical concrete culvert pipe connected by steel pipe. The sumps may act as crude oil/water separators, draining water off the bottom into the drainage ditch. The sumps appear to be open-bottomed, so that some of the drainage from the washrack may infiltrate into the ground between Building 850 and the ditch, instead of flowing to the ditch. It was also observed that the sumps are often clogged, and overflow runoff from the washrack flows overland directly to the ditch.

#### 1.4.2.6 Discharge Area 6 (DA-6)

Discharge Area 6 corresponds to the area of the old industrial wastewater evaporation pond operated from approximately 1960 to 1977, adjacent to the STP. A system of industrial sewers separated from the sanitary sewers was installed at CAFB in the early 1960's to collect oily wastes segregated in oil/water separators at the source areas. These wastes were discharged to a closed evaporation pond, DA-6. It was in use until 1977, when a spray irrigation program for wastewater effluent began. According to ESI, the water discharged to DA-6

"... consisted primarily of water contaminated with solvents and oils. Chemical analyses of the industrial wastewater tested in 1973, revealed high concentrations of COD (maximum 4350 mg/l) and surfactants (maximum 600 mg/l) and occasionally high concentrations of phenol (maximum 87 mg/l). The evaporation pond was unlined and had dimensions 2 feet deep by 1.5 acres. The pond was closed in 1977 and at that time was partially filled with soil and covered with grass. No clean-up efforts were undertaken when the pond was closed. The State of California did however request an analysis of soil samples from the area where the pond was located. Soil samples were analyzed from a soil boring which extended to a depth of ten feet. ... The State indicated in a transmittal letter to the Base that the results of the analyses did not show any significant concentrations of contaminants."

#### 1.4.3 South Sector

The South Sector includes seven potential source sites: landfills 1 and 2, discharge area 1, and disposal pits 1 through 4. Figure 1-5 is a map of the South Sector showing the locations of the sites investigated in the Phase II, Stage 1 study. Other locations are shown in Figure 1-2. For the groundwater portion of this investigation, the seven source sites were grouped into a single investigation site, referred to in the task order as the South Landfill Zone (SLFZ).

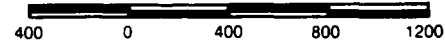
##### 1.4.3.1 Landfill 1 and Disposal Pits 1, 2, and 3 (LF-1, DP-1, DP-2, and DP-3)

Landfill 1 consists of approximately 30 acres of land that were used for disposal between 1940 and 1950. It has a triangular shape and is bordered on two sides by perimeter drainage ditches, near the surface water exit point for the Base. According to ESI, wastes consisting of general refuse were placed in trenches and burned daily. Operations were discontinued when a neighboring rancher complained of smoke.





Three disposal pits were located on the perimeter of the landfill. DP-1, on the southern tip, was used to bury radioactive vacuum tubes sealed in concrete. DP-2, on the southwest side, received sludge and cyanide wastes from small cadmium plating and metal parts heat treatment operations. DP-3, on the east side, was reportedly used to bury drums of chemicals.

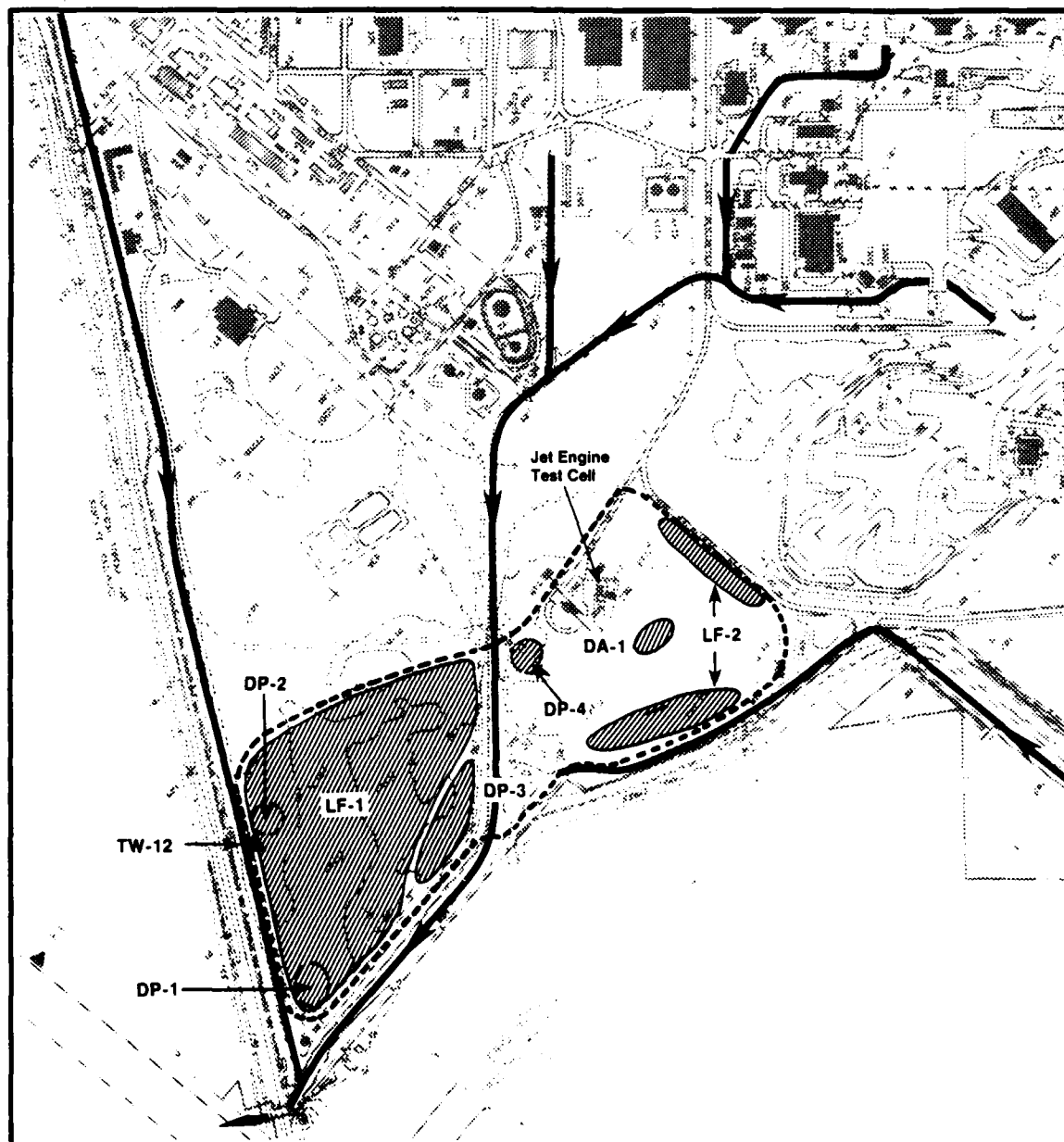


Scale in Feet



**Legend**

-  Phase II Investigation Site
-  Boundary of SLFZ
-  Open Ditch
-  Test Well



**FIGURE 1-5 SOUTH SECTOR MAP**

In late 1984 the perimeter ditch between Santa Fe Boulevard and LF-1 was moved approximately 50 feet northeast (toward the landfill) to make room for widening of Santa Fe Boulevard. Although the new ditch was excavated to depths of 5 to 15 feet, no evidence of soil staining or loose refuse was found in the material excavated.

#### 1.4.3.2 Landfill 2 (LF-2)

Landfill 2 (LF-2) is located northeast of Landfill 1 on the southeast Base perimeter. According to ESI, LF-2 consists of only two trenched areas, each about 400 feet long, which primarily received general refuse.

#### 1.4.3.3 Discharge Area 1 (DA-1)

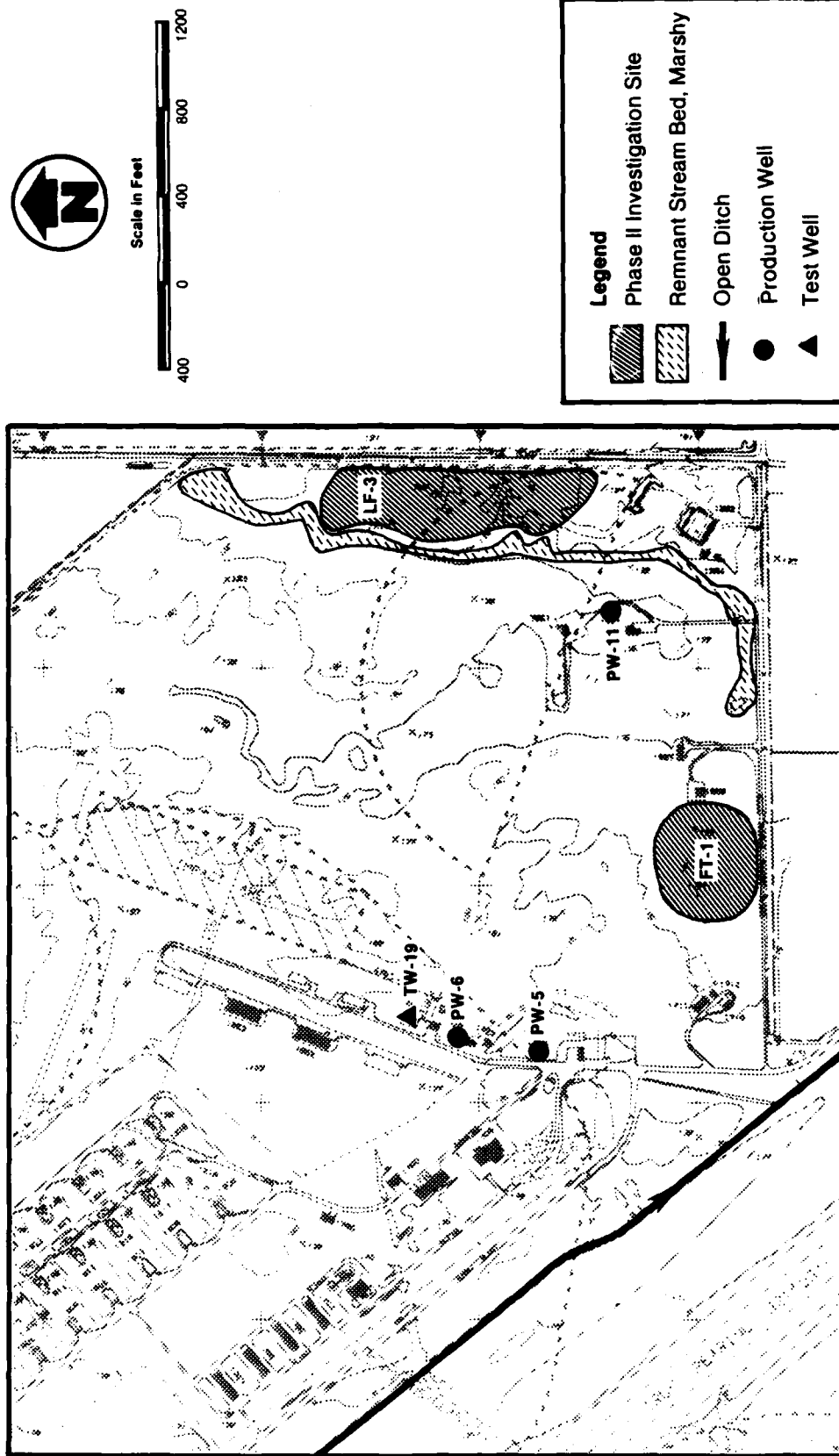
Discharge Area 1 consists of a topographical depression just east of the Jet Engine Test Cell (Buildings 949 to 955). The depression is located between two of the trenches identified by ESI as belonging to LF-2. Runoff from the test stands used to test and washdown jet aircraft engines drains to this depression following distinct runoff swales. Some soil staining can be observed at the surface in the swales and the depression. The runoff has included JP-4 and associated fuel residues, detergents, and solvents. ESI (1983) reported estimated total discharges to this area of 1,500 gallons of JP-4, 3,500 gallons of PD-680, and 5,500 gallons of detergents since 1956.

#### 1.4.3.4 Disposal Pit 4 (DP-4)

ESI identified a chemical disposal pit, DP-4, on the east side and adjacent to the drainage ditch between Landfills 1 and 2. This pit would have received waste solvents, oils, and other miscellaneous waste chemicals hauled to the pit in bowsters.

#### 1.4.4 East Sector

Figure 1-6 is a map of the East Sector, which includes most of the Weapons Storage Area (WSA), a restricted area of the Base, the dog kennels, and the Rifle Range. In addition, it includes two investigation sites on the Base perimeter: Fire-Training Area 1 and Landfill 3.



**FIGURE 1-6 EAST SECTOR MAP**



#### 1.4.4.1 Fire-Training Area 1 (FT-1)

FT-1 consists of a 1-acre site on which fire-training exercises were conducted from 1955 to 1975. According to ESI, 1983:

"From 1955 to the mid 1970's, combustible waste chemicals were accumulated in a shallow two foot deep unlined pit in the FPTA. These chemicals were reported to have included waste oils, spent solvents, waste Avgas and jet fuel. Chemicals were accumulated weekly and burned in the unlined pit on Saturday or Sunday. Other chemicals were accumulated in 55-gallon drums and applied to a separate burn area which was adjacent to the burn pit. The burn area did not have a liner system nor was there any pre-application of water to prevent the percolation of the waste chemicals into the soil. The materials were applied directly to the soil and ignited. Toward the later period of usage in the 1970's, a 2,000-gallon tank was installed at the FPTA to accumulate some flammable chemicals. Aerial photos from 1972 indicate the chemical pit was still in use. No provision was made for collecting runoff from either the pit or burn area after a training exercise."

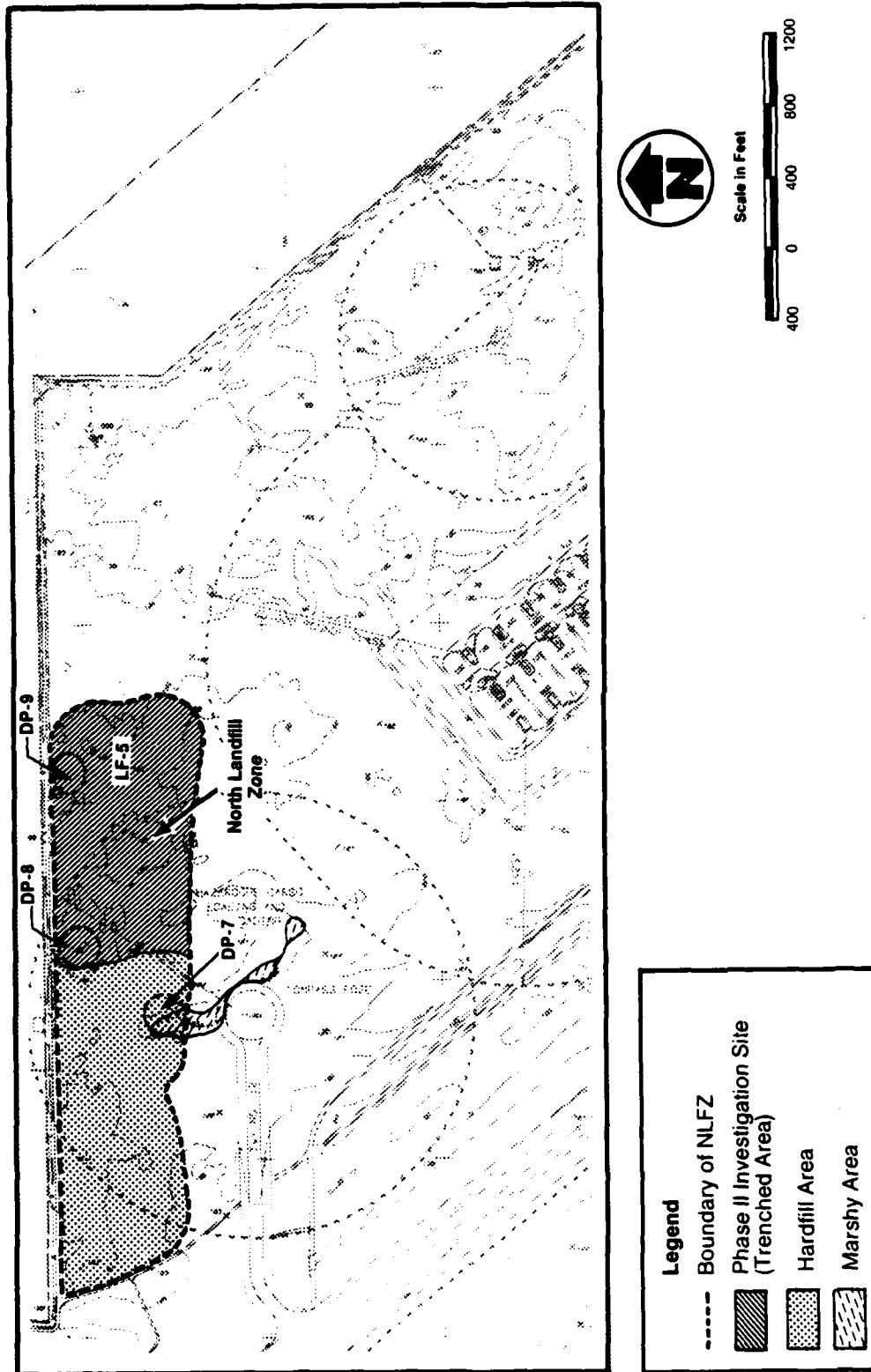
The site has since grown over with vegetation and an antenna has been constructed over it.

#### 1.4.4.2 Landfill 3 (LF-3)

LF-3 consists of a 2-acre site on which shallow trenches were excavated and filled with general refuse, possibly including small volumes of chemical wastes. The landfill operation was reportedly abandoned due to poor drainage and the presence of hardpan in the soil at a depth of approximately 8 feet. Landfill trenches on the site are clearly outlined due to differential settlement. Weathered refuse can also be observed at the land surface.

#### 1.4.5 North Sector

The North Sector (Figure 1-7) is the area of CAFB most remote from the main Base industrial activities; it was the last area to be developed for disposal operations. It includes Landfill 5 and associated Disposal Pits 7 through 9. These sites have been grouped together into a single investigation site, referred to as the North Landfill Zone (NLFZ) in the task order.



**FIGURE 1-7 NORTH SECTOR MAP**



#### 1.4.5.1 Landfill 5 and Disposal Pits 7, 8, and 9 (LF-5, DP-7, DP-8, and DP-9)

Landfill 5 consists of an 85-acre site running east-west along the northern perimeter. It was operated as a trench-and-fill landfill from 1971 to 1977, and received primarily general refuse. According to ESI (1983), however, at least one trench was used for drum disposal. There are conflicting reports as to whether these drums were empty or filled with chemical wastes. Landfill trenches are clearly outlined due to differential settlement, and appear to be confined to the eastern half of the site. The western half has been used for surface disposal of hardfill wastes, including demolition debris and asphalt and concrete rubble. Based on a review of aerial photography, hardfill disposal on the western half of the site appears to have begun before the start of the trenching operations on the eastern half. A detailed description of LF-5, based on extensive review of aerial photography, field reconnaissance, and surface geophysics, is provided in Section 4.

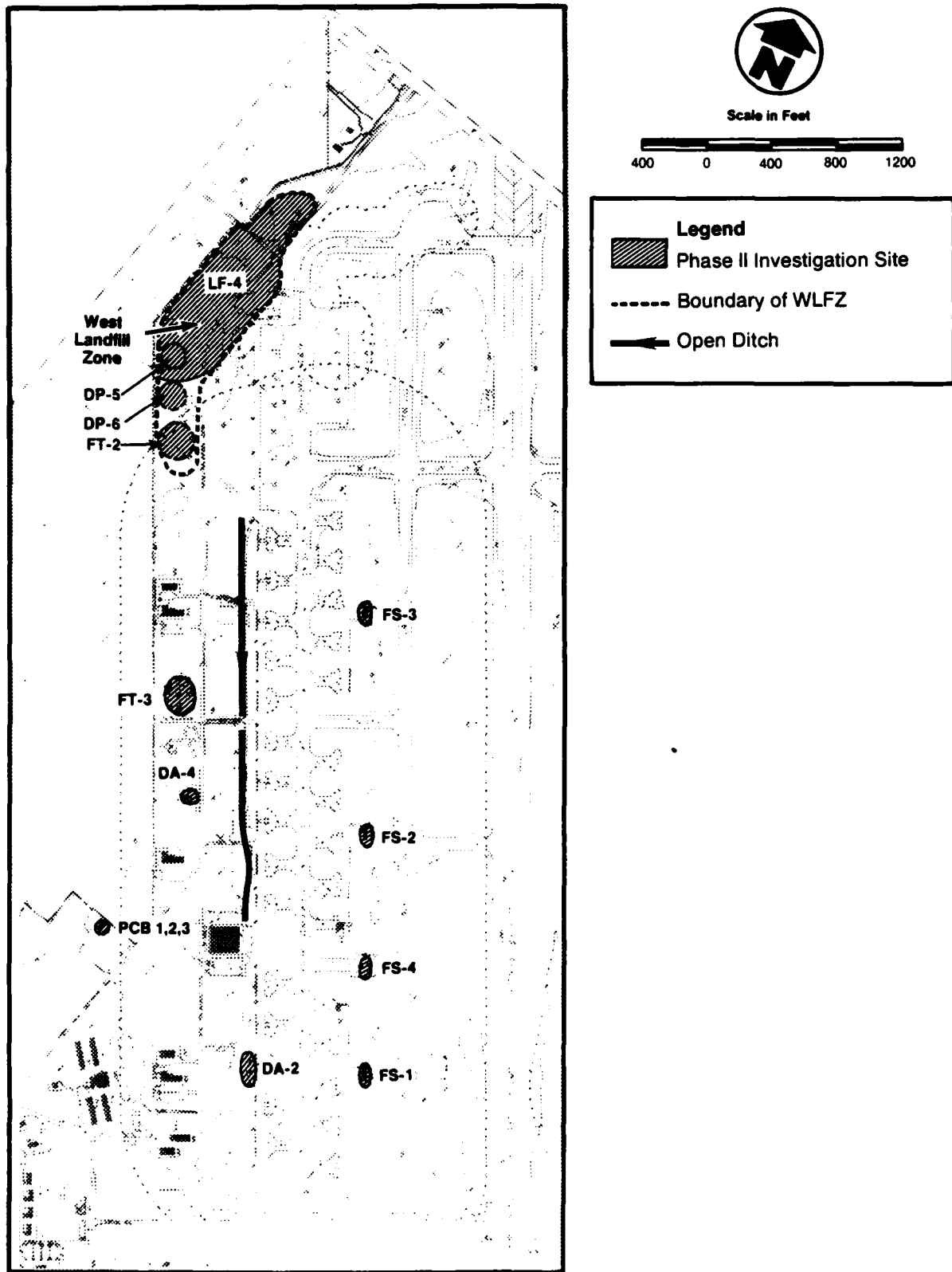
According to ESI, Disposal Pits 7, 8, and 9 could not be accurately located, but approximate locations are shown in Figure 1-2. DP-7 and DP-8 reportedly received mostly waste oils and sludge from tetraethyl lead gasoline storage tanks. DP-9 received miscellaneous chemical wastes including solvents and oils.

#### 1.4.6 West Flightline Sector

The West Flightline Sector includes the flightline north of the operational apron, the B-52 hardstands, and the northwest perimeter areas (Figure 1-8). There are six investigation sites located in the West Flightline Sector; these are described below.

##### 1.4.6.1 West Landfill Zone (WLFZ)

The West Landfill Zone (outlined in Figure 1-8) includes four potential source sites: Landfill 4 (LF-4), Disposal Pit 5 (DP-5), Disposal Pit 6 (DP-6), and Fire-Training Area 2 (FT-2). Individual site locations are shown in Figure 1-2.



**FIGURE 1-8 WEST FLIGHTLINE SECTOR MAP**



Landfill 4 is the largest landfill at the Base, comprising over 14 acres according to ESI (1983). It was used from 1957 to 1970 for disposal of general refuse. Only small volumes of chemicals, if any, are suspected of having been disposed of at the landfill. On the southern two-thirds of the area outlined by ESI, eastwest oriented landfill trenches are clearly outlined by differential settlement. There is no evidence, either in aerial photographs or in direct field observation, of trench-type landfilling on the northern third (north of the boundary gate access road). This area was part of an agricultural field and was only incorporated in the Base between 1957 and 1961, when a small segment of the Arundel Lateral Canal was diverted around it.

Disposal Pits 5 and 6 were used for disposal of miscellaneous chemical wastes, including oils and solvents, during the period of landfill operation. The locations in Figure 1-2, as identified by ESI, are only approximate.

Fire-Training Area 2 was reportedly operated from 1962 to 1967 as an alternate to FT-1 on the east perimeter. According to ESI, "FT-2 was used intermittently for training civilian firemen from nearby county and city fire departments in the use of foam extinguishers. The burn area was unlined and no provision was made for collecting runoff from the training exercise." No clear evidence for the exact location of FT-2 was gained from a review of aerial photographs. In general, there has been considerable disturbance of soils in the west perimeter area just south of LF-4, as this area has been used for stockpiling and removal of topsoil and other hardfill materials.

#### 1.4.6.2 PCB Spills 1, 2, and 3 (PCB)

The area of PCB Spills 1, 2, and 3 is within the fenced DPDO storage yard at its western end in front of Building 1203. The spills occurred from a broken transformer stored in the yard (October 1982), a leaking drum of PCB oil (1982-1983), and a drum full of PCB-contaminated soil which was knocked over (February 1984). Three rounds of cleanup had been conducted as of early 1985, with concentrations of PCB's in excavated soils ranging up to 7,600 ppm. Based on a round of samples collected by the Base in September 1984, a fourth and final round of cleanup was completed in July 1985, after the end of this investigation.

#### 1.4.6.3 Fuel Spills 1, 2, 3, and 4 (FS-1 through FS-4)

Major fuel spills at CAFB which might have had a long-term environmental impact were associated primarily with the fuel transfer and hydrant system installed in the early 1950's. The main line was parallel to the flightline, between taxiway 1 and the B-52 hardstands. Three pumphouses along the line (Buildings 1401, 1402, and 1403) experienced operating problems resulting in significant fuel spills until 1977, when the piping was re-designed. The largest of these spills occurred at Building 1403. It was estimated that 21,000 gallons were spilled, of which only 1,000 gallons were recovered. The remainder was washed to the surface drainage system and either evaporated or infiltrated the soils. Another spill occurred in the 1960's under taxiway 9, and was attributed to a break in the fuel transmission line. The spill was discovered when the ground was observed to be saturated with fuel. The quantity spilled was unknown (ESI, 1983).

#### 1.4.6.4 Discharge Area 2 (DA-2)

Discharge Area 2 is located on the west end of the B-52 hardstand 6. It corresponds to the nonpowered AGE washrack, which is used to clean aircraft support equipment, such as generators. Wash water from the washrack, containing detergents, solvents, and oils, drains to a concrete sump. The sump is emptied by a pump which spreads the wastewater over the soil southwest of the washrack. According to ESI (1983), the receiving soils were devoid of vegetation and had a distinct oily coloration. Some of the washwater runs off into a swale which carries it into the surface drainage system; the rest infiltrates the soils immediately adjacent to the washrack.

#### 1.4.6.5 Discharge Area 4 (DA-4)

Discharge Area 4 is adjacent to the liquid oxygen (LOX) plant, Building 1316. According to ESI, filters at the plant were regularly cleaned with TCE between the early 1950's and 1980. TCE usage at the plant was estimated at 150 gallons per year. Spent TCE was reportedly disposed by pouring on the adjacent soils in the area in small quantities so that most would have been expected to evaporate before infiltrating the ground.



#### 1.4.6.6 Fire-Training Area 3 (FT-3)

Fire-Training Area 3 is the current fire protection training area. It is located approximately 500 feet northwest of the LOX plant, on the western perimeter; it has been operated since 1976. It consists of a circular area 300 feet in diameter, surrounded by a 2-foot berm. A drain in the center of the pit directs runoff to an oil/water separator, and discharge from the oil/water separator infiltrates through an underground tile field. Recently (1984), this drain has backed up, and the berm has been breached to allow runoff to flow along the ground surface and infiltrate in the field northwest of the burn pit. This pit has been operated by saturating the ground with water prior to applying the combustible materials, and by burning contaminated jet fuel only. No solvents or other chemicals are known to have been disposed of at this site.

#### 1.5 FACTORS OF CONCERN

There are several factors which influence the potential for environmental impact of ongoing and historic Base activities and of the specific sites identified in the Phase I study. The reader should be aware of these factors in reviewing the following sections on the environmental setting of CAFB and on the Phase II field program development and implementation, and in evaluating the findings of this study:

- TCE and other VOA compounds at trace levels have been found in some off-Base residential wells along the southwestern Base boundary. There is an ongoing cooperative program between CAFB and the state and county to monitor TCE levels in the shallow aquifer on and off Base, and to provide affected homes with suitable water treatment systems. Public and private drinking water supply in the area is entirely from groundwater sources. Agricultural water supply is from a combination of surface and groundwater sources. There is considerable public concern over the potential for further migration of contaminants from the Base to off-Base areas. Partly in response to this concern, the State of California has recently (Fall 1984) declared Castle Air Force Base a Superfund site.



- Soils underlying the installation and surrounding areas are sandy and generally permeable, but locally include a low-permeability zone, or hardpan, occurring 5 to 15 feet below the ground surface. As a result, soil drainage in the area is poor, especially moving eastward from the Base. Where this layer is continuous and has not been breached artificially, it could form a barrier to downward migration of contaminants.
- There are at least three aquifers, or water producing zones, identifiable beneath Castle Air Force Base. The shallow aquifer, made up of sands and gravels occurring above a level of 100 feet below ground surface, is known to be contaminated with TCE in the Main Base Sector. This determination is based on samples gathered from existing test wells in that aquifer. Base production wells in the main Base area are open to a deeper intermediate aquifer, separated from the shallow aquifer by at least 150 feet of mixed clayey sediments. Three production wells completed in this intermediate zone have also exhibited significant levels of TCE, although these levels have remained lower than in the shallow aquifer. The primary mechanism for contaminant migration from the shallow to the confined aquifer is thought to be provided by the production wells themselves, through the disturbed, relatively more permeable outer casing zone created by cable tool well installation methods. Pilot borings for a new production well have indicated that several deeper water-producing sands, each separated by substantial clay zones, exist at depths between 300 and 800 feet.

## 1.6 PROJECT TEAM

The Phase II, Stage 1, Problem Confirmation Study at CAFB was conducted by staff personnel of Roy F. Weston, Inc. and was managed through WESTON's home office in West Chester, Pennsylvania.

### 1.6.1 WESTON Personnel

The following personnel served lead functions in this project:

Peter J. Marks, Program Manager: Corporate Vice President, Master of Science (M.S.) in Environmental Science, 20 years experience in laboratory analysis and applied environmental science.



Frederick Bopp, III, Ph.D., P.G., Project Manager (until April 1985): Manager of the Geosciences Department, Doctor of Philosophy in Geology and Geochemistry, Registered Professional Geologist, over 8 years experience in hydrogeology and applied geological sciences.

Katherine A. Sheedy, P.G., Project Manager (after April 1985): M.S. in Geology, Registered Professional Geologist, 11 years experience in hydrogeology and environmental geology.

Alison L. Dunn, P.G., Project Geologist: M.S. in Hydrogeology, Registered Professional Geologist, over 3 years experience in hydrogeological site evaluation.

Deborah L. Jones, Assistant Soil Scientist: M.S. in Environmental Pollution Control, 2 years experience in investigation of soil and groundwater contamination.

Walter M. Leis, P.G., Geotechnical Quality Assurance Officer: Corporate Vice President, M.S. in Geological Sciences, Registered Professional Geologist, over 15 years experience in hydrogeology and applied geological science.

David Ben-Hur, Ph.D., Project Chemist: Manager of WESTON Laboratory Services in Stockton, over 20 years experience as a senior chemist specializing in the analysis of environmental and hazardous waste samples and waste compatibility testing.

Margaret G. Neckels, Sampling Specialist: B.A., over 7 years experience in laboratory analytical methods, field analytical methods, and collection of environmental and hazardous waste samples.

Professional profiles of these key personnel, as well as other project personnel, are contained in Appendix C.

#### 1.6.2 Subcontractors

Soil borings, drilling, and well installation for this project were performed by the Stang Drilling and Exploration Company, Inc. of Rancho Cordova, California.

All well and staff gauge elevations were surveyed for this project by Larsen, Ohlinger and Hill, Inc. of Merced, California.

Laboratory analyses of soil and water samples for oil and grease, TOC, and phenols were performed by EAL Corporation of Richmond, California.



## SECTION 2

### ENVIRONMENTAL SETTING

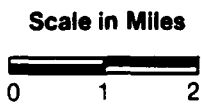
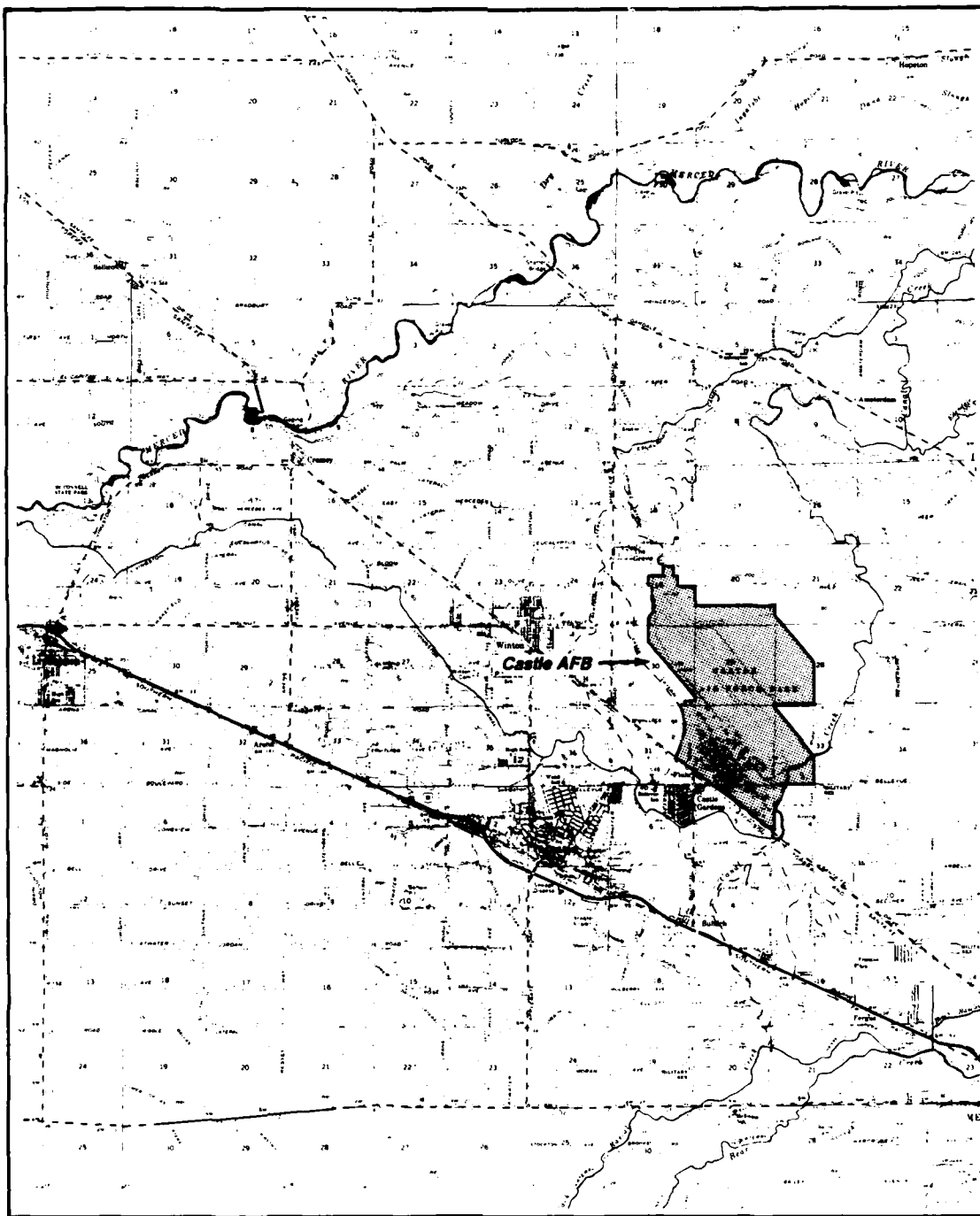
Sources of information on the environmental setting of CAFB include the climatic records of the U.S. Department of Commerce National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Agriculture (USDA) Soil Conservation Service soil survey for Merced County, and the following publications on regional geology and hydrogeology: California Division of Mines and Geology (CDMG, 1966), Page and Balding (1973), Page (1977), and Templin (1984). These sources and additional information from publications and interviews with public officials were summarized in the IRP Phase I report for CAFB (ESI, 1983).

#### 2.1 GEOGRAPHY

CAFB is located in Merced County, approximately in the geographic center of the State of California, adjacent to the Town of Atwater, about 8 miles northwest of the City of Merced (Figure 1-1).

##### 2.1.1 Topography

Physiographically, the Base is located in the San Joaquin Valley which forms the southern half of the Great Valley of central California. This valley is a north-south trending, flat-bottomed valley approximately 400 miles long and an average of 40 miles wide. The San Joaquin Valley in the vicinity of CAFB is approximately 45 miles wide and is bounded by the Sierra Nevada Mountains on the east and the Diablo Range (part of the coastal ranges) on the west. This valley is drained along its western edge by the San Joaquin River, which flows northwest to the Sacramento-San Joaquin delta region that links drainage from the central valley to the San Francisco Bay. The valley floor in the vicinity of CAFB slopes gently to the west-southwest, and natural drainage in the area is to the southwest, approximately perpendicular to the flow direction of the San Joaquin River. CAFB is located about 16 miles from the river, approximately halfway between it and the eastern edge of the valley. It is located about halfway between two southwest-flowing tributaries to the San Joaquin River, the Merced River, and Black Rascal Creek (Figure 2-1). Total relief at CAFB is about 35 feet, ranging from 200 feet above mean sea level (MSL) at the northwestern corner to 165 feet MSL at the exit point for surface drainage on the southern boundary corner.



**FIGURE 2-1 TOPOGRAPHIC SETTING OF CASTLE AFB**

### 2.1.2 Climate

The climate in the San Joaquin Valley is arid, characterized by dry, hot summers and cool winters (Templin, 1984). According to ESI (1983), the average annual temperature is 62°F; monthly averages range from 46°F in January to 80°F in July. The average annual precipitation is 12.2 inches, but varies greatly from year to year (ESI, 1983). Approximately 89 percent of the annual precipitation falls from November through April; only 2 percent falls from June through September.

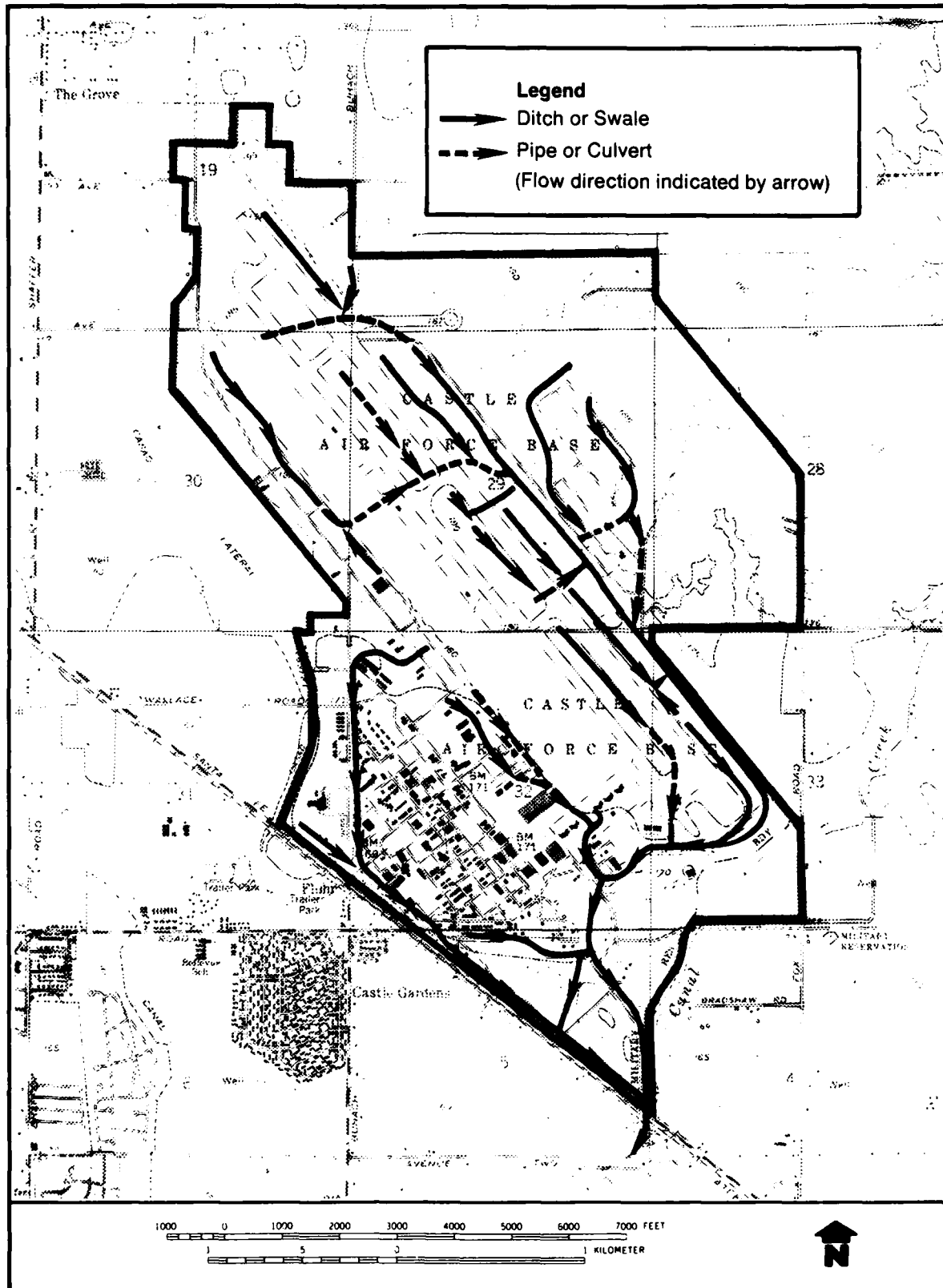
The mean annual potential evapotranspiration for the area of CAFB is 53 inches, yielding an average annual net precipitation (actual precipitation minus potential evapotranspiration) of -41 inches.

### 2.1.3 Surface Drainage

The natural surface drainage in the area of CAFB is to the west-southwest, but has been substantially altered by the network of canals and drains which was developed concurrently with agriculture in the area (Figure 2-1). Canal Creek, flowing north-south just beyond the eastern boundary of the Base, carries water from a dam on the Merced River northeast of the Base to the agricultural lands east and southeast of the Base, eventually draining to Black Rascal Creek downstream from Merced. Another canal, the Escaladian Canal, brings water from the Main Canal off the Merced River to agricultural lands northwest and west of the Base. Drainage southwest of the Base is provided by the Livingston Canal, flowing southeast-northwest just beyond the southwestern Base boundary, eventually draining to the Merced River above its confluence with the San Joaquin River.

Streams in the vicinity of CAFB, both natural and man-made, occur above the water table, so that they lose water to infiltration. These losses may be slowed, in some cases, by the presence of hardpan soils beneath the stream bottom.

The surface drainage system at CAFB is shown in Figure 2-2. It consists of storm drains and open channels which carry all runoff generated on-Base to the southern boundary corner, which constitutes the single exit point for runoff from the Base. The runoff is contained by a weir at this point, and discharges through culverts under Santa Fe Boulevard only during heavy rainfall events. At such times, the culverts carry Base drainage



**FIGURE 2-2 SURFACE DRAINAGE MAP OF CASTLE AFB**

under the Boulevard, under the Santa Fe Railroad tracks, and under the Livingston Canal to Canal Creek. According to ESI (1983), some partial discharge to the Livingston Canal occurs during extreme storm events.

## 2.2 SOILS

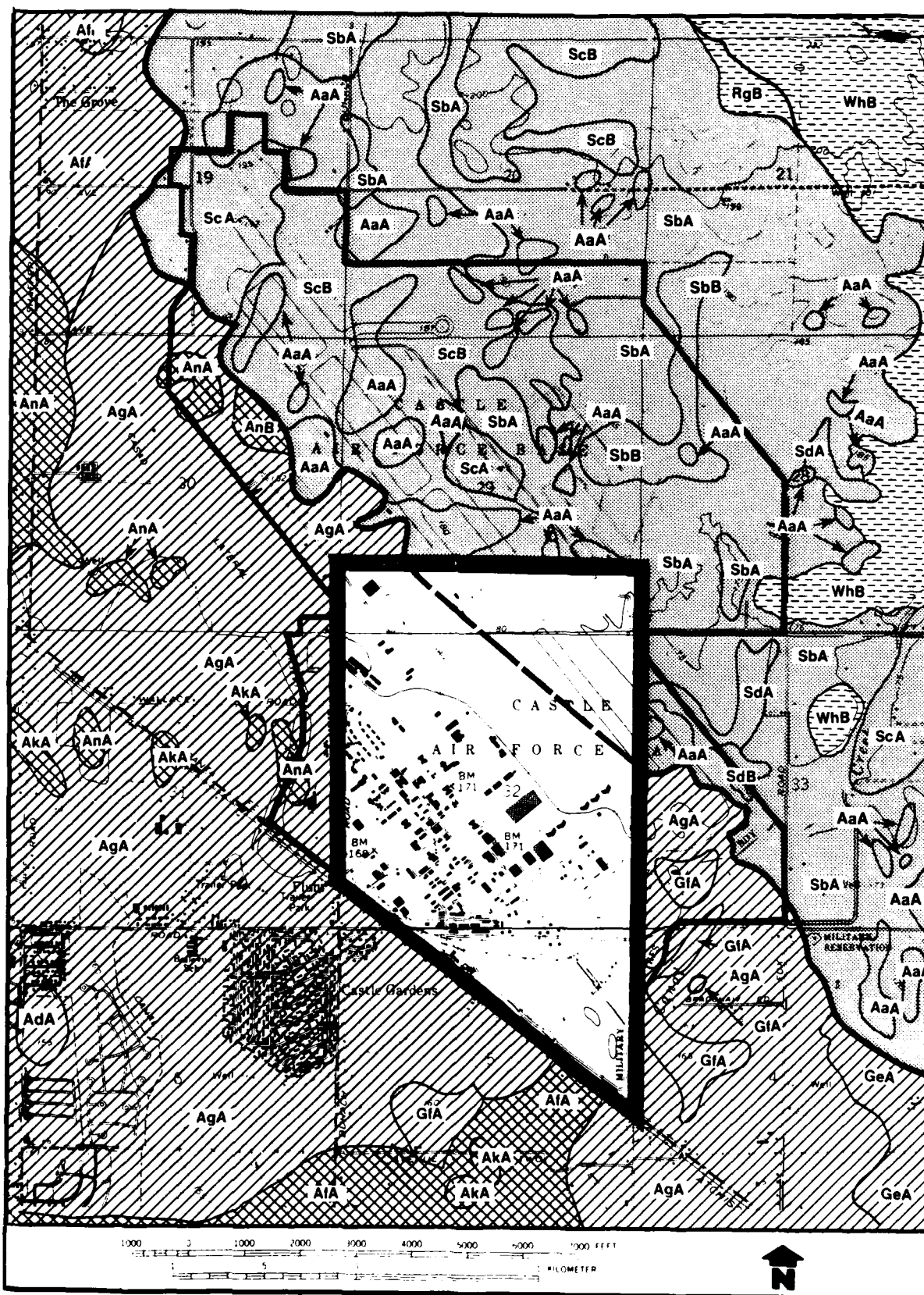
Figure 2-3 is a soils map for the area surrounding CAFB, taken from the SCS soil survey for Merced County (USDA, 1950). The mapping was done in 1950, and for security reasons the area of Castle Field could not be included in the aerial photo maps at that time. However, mapping was done in perimeter areas which have since been incorporated into the Base.

Three principal soil associations can be distinguished in the vicinity of CAFB: the Whitney-Rocklin association to the northeast, the San Joaquin-Alamo association in a northwest-southeast trending band across the Northeastern Sector of the Base, and the Atwater-Greenfield association in the West and Southwest Sectors of the Base (including the Main Base and South Sectors).


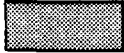



The Whitney-Rocklin soils are loams and fine sandy loams derived from granitic high-terrace alluvial sediments. They are generally well-drained and do not include a hardpan layer. Whitney fine sandy loam is found only on a small portion of the Base, in the eastern corner in the area of the Rifle Range.

The San Joaquin soils are loams and sandy loams derived from granitic low-terrace alluvial sediments. They are well-drained due to the relatively high permeability of the surface soils, but internal drainage is very slow due to hardpan in the subsoil. They are old and strongly weathered, and characteristically exhibit "hogwallow," or mound-and-depression, microrelief. The San Joaquin soils are closely associated with Alamo clays, consisting of poorly-drained clayey surface soils underlain by cemented hardpan at depths of 20 to 30 inches. A typical profile in the San Joaquin-Alamo association consists of reddish-brown sandy loam down to about 13 inches, underlain by 3 to 6 inches of hard blocky sandy clay loam, followed by 2 to 6 inches of hard gritty clay pan, underlain by a 6- to 16-inch rock-hard brownish-red iron-silica hardpan.

The Atwater-Greenfield soils are sands, loamy sands, and sandy loams derived from sandy granitic alluvial fan sediments. Surface soils are generally well-drained, but subsoils in some cases include a relatively impermeable hardpan. Atwater soils are moderately weathered and, in their undisturbed state, characteristically exhibit a gently undulating relief that is largely the result of wind action. The most prevalent soil type within this association in the vicinity of CAFB is the Atwater



### Legend

	Whitney-Rocklin Association (Soils of High Terraces)
	San Joaquin- Alamo Association (Soils of Low Terraces)
	Atwater-Greenfield Association (Soils of Alluvial Fans)
	Atwater Soils Without Hardpan
	Area Not Mapped by USDA-SCS (1962)

### Symbol

### Soil Name

#### Atwater-Greenfield Association

Ad	Atwater Loamy Sand, Deep Over Hardpan, Poorly-Drained
Ag	Atwater Loamy Sand, Deep Over Hardpan
Al	Atwater Loamy Sand
Ak	Atwater Loamy Sand, Imperfectly Drained
An	Atwater Sand
Ge	Greenfield Sandy Loam, Deep Over Hardpan, Poorly-Drained
Gl	Greenfield Sandy Loam, Deep Over Hardpan

#### San Joaquin-Alamo Association

Sb	San Joaquin Loam
Sc	San Joaquin Sandy Loam
Sd	San Joaquin-Alamo Complex
Aa	Alamo Clay

#### Whitney-Rocklin Association

Rg	Rocklin Loam
Wh	Whitney Fine Sandy Loam

Note: Suffix A: 0 to 3% Slopes  
Suffix B: 3 to 8% Slopes

**FIGURE 2-3 LEGEND FOR SOIL MAP**

loamy sand, deep over hardpan (Ag). This soil consists of a light-brown loamy sand underlain by an iron-silica cemented hardpan at 3.5 to 5 feet; transition to the hardpan is abrupt. Within this primary soil type are patches of associated soils that do not have hardpan, such as Atwater loamy sand (Af) and Atwater sand (An), both relatively well-drained, and Atwater loamy sand, imperfectly drained (Ak). This suggests that hardpan subsoils are not necessarily continuous beneath CAFB.

ESI (1983) reviewed a large number of shallow soil boring logs associated with foundation studies and other construction projects, available from CAFB Civil Engineering. Their report states:

"...that the base is generally underlain by several feet of sand, silty sand, and sandy silt, with a decrease in grain size with depth. In places these materials are abruptly underlain by iron-silica cemented hardpan varying in thickness from one to more than five feet. When identified, the hardpan is generally found less than five feet from the ground surface."

According to ESI (1983), an attempt to draw cross-sections through the shallow subsurface revealed that hardpan beneath the Base is extremely variable within short distances.

## 2.3 GEOLOGY

### 2.3.1 General

The San Joaquin Valley is a deep northwest-southeast trending structural trough. It is bounded on the east and west by steep bedrock mountains and filled with Cretaceous, Tertiary, and Quaternary sediments of the Great Valley sequence. The Sierra Nevada Mountains to the east consist of a tilted fault block of igneous and metamorphic crystalline rock, with a sharp escarpment to the east and a relatively gradual westward slope forming the eastern boundary of the valley.

The sedimentary deposits underlying the valley floor consist of older consolidated sedimentary rock formations overlain by younger, unconsolidated Quaternary Age sediments. The older valley fill deposits were formed under marine conditions, and were derived from erosion of the ancestral Sierra Nevada range as it rose to the east. During the Tertiary Age, the coastal ranges formed along the western margin of the Great Valley, eventually making it a closed basin, and resulting in increased

deposition of sediments derived from mountains along both the eastern and western margins. As both the mountains and valley floor rose, the sea retreated from the valley, and vast quantities of unconsolidated sediment were deposited under continental conditions, as coalescing alluvial fans built further and further out into the valley. The eastern alluvial fans, built from sediment of Sierra Nevada origin, consist primarily of granitic materials with a high quartz content. In general, the thickness of alluvial sedimentary deposits increases and particle size decreases away from the mountain fronts and toward the valley axis, moving from relatively high-energy to low-energy depositional environments. Formations dip gently to the west-southwest, and progressively younger sediments are encountered at the surface moving southwestward from the Sierra Nevada foothills to the valley floor.

CAFB is built on an old alluvial fan of the Merced River which has been exposed and leveled by progressive downcutting of the Merced and its tributaries, and the action of wind erosion. Two separate physiographic terrains can be distinguished within the area of CAFB (Page, 1977) -- low alluvial plain in the South and Main Base Sectors, and dissected upland in the East, North, and most of the West Flightline Sectors. The boundary between these two terrains corresponds to the boundary between the Atwater-Greenfield and the San Joaquin-Alamo soil associations mapped in Figure 2-3. Surface geology in the plain and upland has been mapped respectively as Recent dune sand and Pleistocene non-marine deposits (CDMG, 1966), Recent dune sand and Plio-Pleistocene continental deposits (Templin, 1984), and Pleistocene to Recent older alluvium throughout (Page, 1977). It appears that in the south-southwest (plains) sectors of the Base, Recent dune sand forms a relatively thin mantle over Pleistocene older alluvium, and in the north-northeast (uplands) sectors shallow sediments are in the transition zone between Pleistocene older alluvium and Plio-Pleistocene continental deposits. Further definition and description of these geologic units are provided below.

### 2.3.2 Stratigraphy

Geologic formations in the San Joaquin Valley range in age from Pre-Cretaceous to Recent. The dune sands are the youngest sediments found in the area of CAFB. They form a relatively thin veneer over Quaternary (Pleistocene and Recent) sediments, referred to as Quaternary basin and fan deposits by CDMG (1966). In Page and Balding (1973), these same sediments are broken into

flood-basin deposits, younger alluvium, older alluvium, and lacustrine and marsh deposits. Of these, only the older alluvium, with interbedded lacustrine and marsh deposits, occurs in the vicinity of CAFB, to depths of 300 to 400 feet. The older alluvium is underlain by somewhat older (Pliocene and Pleistocene) continental deposits, which unconformably overlie consolidated sedimentary rock formations at depths of 600 to 700 feet.

Table 2-1, modified from Page and Balding (1977; ESI, 1983), summarizes the lithology and water-bearing properties of the principal stratigraphic units commonly identified in the vicinity of CAFB. Descriptions of the major lithologic units which comprise the freshwater-bearing section beneath CAFB, taken from Page (1977), are briefly reviewed below:

- The Pleistocene older alluvium consists of interbedded gravels, sands, silts, and clays with some hardpan layers. According to Page and Balding (1973), it probably becomes less permeable with depth. In the Merced area, it ranges in thickness from 0 to at least 375 feet.
- The Pleistocene lacustrine and marsh deposits are interbedded with the older alluvium, and include two distinct beds which can be considered stratigraphically continuous across large areas: the Corcoran Clay Member of the Plio-Pleistocene Tulare Formation (also referred to as E-clay), and a shallow clay bed of Recent age. The Corcoran Clay Member is a bed of gray and blue silt, silty clay, and clay, 10 to 30 feet thick, and occurring approximately 100 feet below ground surface in the area of CAFB. The Recent shallow clay bed consists of brown, red, gray, and blue sandy clay and clay, as well as some hardpan. It is 5 to 20 feet thick, and occurs 15 to 35 feet below ground surface. The shallow clay was hypothesized by Page (1977) to be continuous beneath the area of CAFB. According to Page (1977), numerous other silt and clay beds occur in the area, but cannot be correlated over long distances.
- The Plio-Pleistocene continental deposits consist of poorly-sorted gravel, sand, silt, and clay, and are generally finer grained than the overlying older alluvium. In the Merced area, the continental deposits are thicker to the southwest, ranging in thickness from 110 to at least 330 feet.

Table 2-1

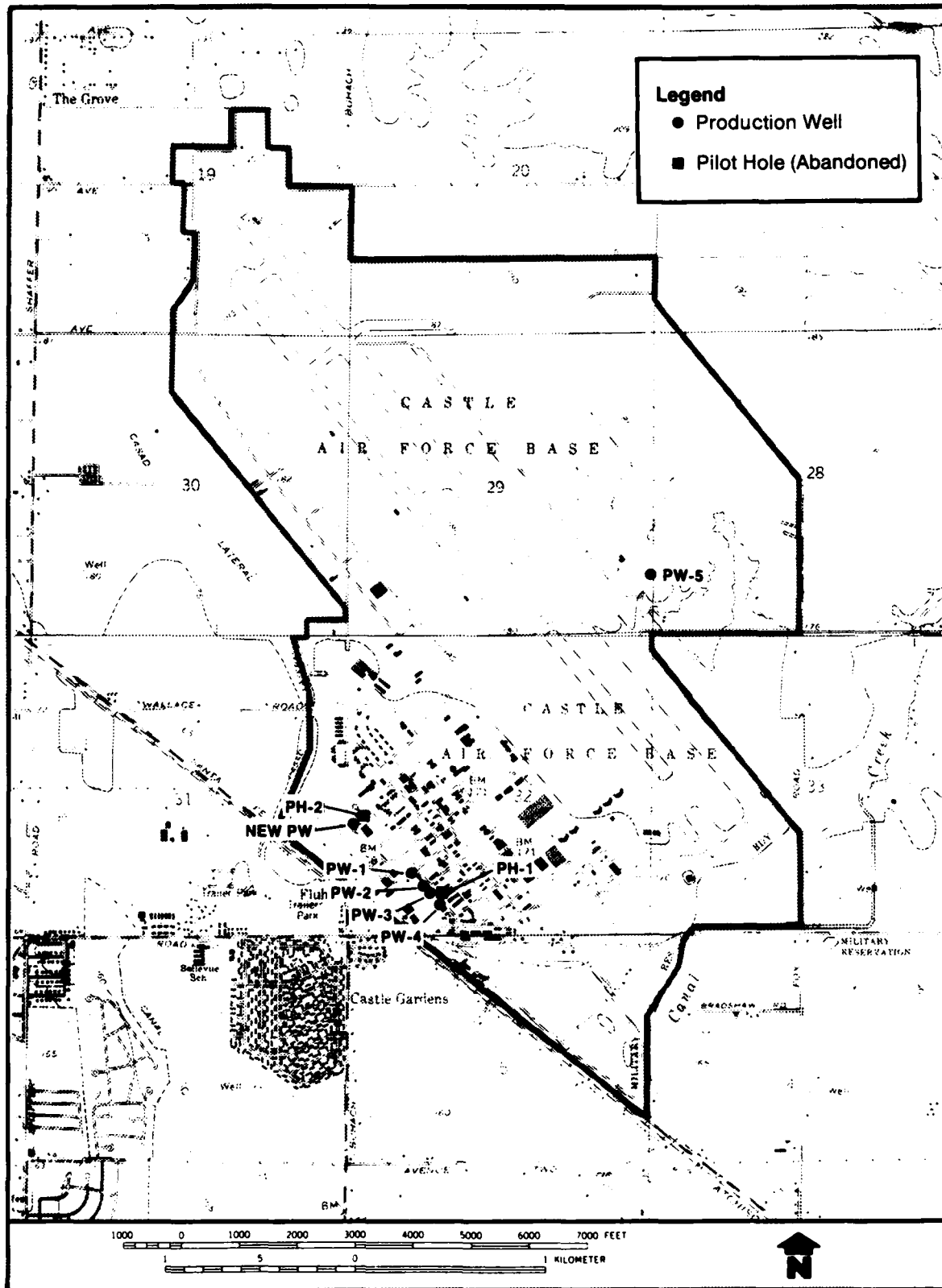
Stratigraphic Units of the Eastern San Joaquin Valley

System and Series	Geologic Unit	Lithology	Range of Thickness (feet)	Water-Bearing Characteristics
<u>Unconsolidated Deposits</u>				
<u>QUATERNARY</u>				
Recent	Flood-basin deposits	Silt, clay, and fine sand; bluish-gray, brown, and reddish-brown.	100	Low hydraulic conductivities and low yields to wells.
	Younger alluvium	Gravel, sand, and fine sand, some silt and clay, little or no hardpan; yellow, yellowish-brown, brown.	100	Moderate to high hydraulic conductivities, where saturated yields moderate quantities to wells. Unconfined.
Pleistocene and Recent?	Older alluvium	Gravel, sand, silt, and clay, some hardpan; brown, reddish-brown, gray, brownish-gray, white, blue, and black.	400-700	Moderate to high hydraulic conductivities, yields to wells reported as high as 4,450 gallons per minute (gpm); average yield to large wells 1,900 gpm. Unconfined and confined.
Pleistocene	Lacustrine and marsh deposits	Silt, silty clay, and clay; gray and blue (the Corcoran clay).	100	Confining bed, very low hydraulic conductivities.
<u>TERTIARY AND QUATERNARY?</u>				
Pliocene and Pleistocene	Continental deposits	Gravel, sand, silt, and clay; brown, yellow, gray, blue, and black.	450-700	Moderate to high hydraulic conductivities; yield to wells as high as 2,100 gpm. Confined beneath lacustrine and marsh deposits.
<u>Consolidated Rocks</u>				
<u>TERTIARY</u>				
Miocene and Pliocene	Mehrten Formation	Sandstone, breccia, conglomerate, tuff, siltstone, and claystone; brown, yellowish-brown, grayish-brown, pinkish-brown, pink, blue, yellow, green, gray, and black. Large amounts of andesitic material occurs in beds.	200-700	Low to moderate hydraulic conductivities. Yield to wells as high as 2,100 gpm.
Miocene	Valley Springs Formation	Ash, sandy clay, and siliceous sand and gravel generally in clay matrix, tuff, siltstone, and claystone; yellow, yellowish-brown, reddish-brown, gray, greenish-gray, white, pink, green, and blue. Rhyolitic material occurs in beds.	900	Probably low hydraulic conductivities. Quality of water ranges from fair to poor.
Eocene	Ione Formation and other sedimentary rock	Conglomerate, sandstone, clay, and shale; partly marine; yellow, red, gray, and white.	800	Probably low to moderate hydraulic conductivities. In places reported to yield saline water.
<u>CRETACEOUS</u>	Marine sandstone and shale	Sandstone and shale.	9,500	Unknown. Reported to yield saline water.
<u>PRETERTIARY</u>	Basement complex	Metamorphic and igneous rocks.		Fractures and joints locally yield small quantities of water; otherwise virtually impermeable.

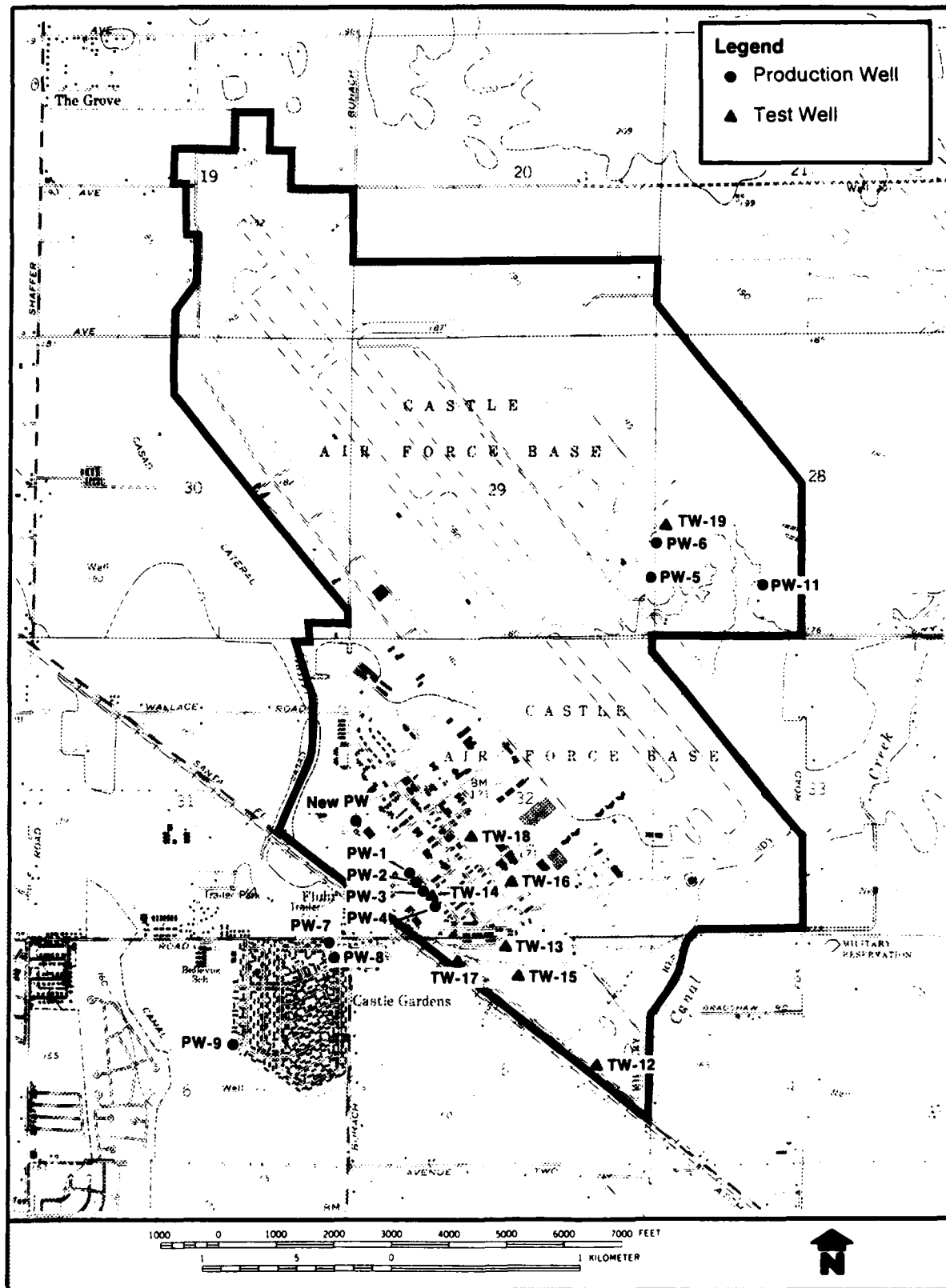
- The Mehrten Formation, occurring below a depth of 500 feet, consists of fluviatile deposits of sandstone, breccia, conglomerate, tuff, siltstone, and claystone, formed from mixed alluvial and volcanic materials. It is characterized by beds of black volcanic sand, and includes beds of dense, hard tuff-breccia. Although it is considered a consolidated formation, the Mehrten is often described by drillers as black packed sand, black sand and gravel, or cemented sand all mixed with red-pink or brown clay or shale. The base of freshwater in the Merced area occurs at about 1,200 feet and is considered to correspond roughly with the base of the Mehrten Formation.

### 2.3.3 Site-Specific Well Logs

Considerable information on the subsurface geology at CAFB is available in drillers' logs for some of the Base production wells (PW1, PW2, PW3, PW4, and PW5). In March 1984, the Base initiated a drilling exploration program to identify a suitable location for a new production well. Two pilot holes, referred to as PH-1 and PH-2, were drilled to depths of 815 and 855 feet by Calwater Drilling of Turlock, California, using mud rotary methods. An electric log of PH-2 was run on 30 March 1984, and the hole was grouted up with cement and bentonite from 400 feet to ground surface on 5 April 1984. The new production well was installed near PH-2 by cable-tool methods to a depth of 804 feet between 29 June and 9 August 1984 by Osterbay and Stewart of Modesto, California. The locations of Base wells and borings for which geologic logs are available are shown in Figure 2-4. Available drillers' and geophysical logs are illustrated schematically in Figures 2-5 (deep borings) and 2-6 (Main Base and East Sector production wells). All available information on the existing Base production wells, compiled by the California Department of Health Services in 1981, is provided in Appendix D. The California well permit for the new production well is also included in Appendix D. The vertical profile for the Main Base area, illustrated in Figure 2-5, appears to be quite consistent from boring to boring. The Mehrten is easily distinguished in the log for the new production well as black sands interlayered with brown sands, clay, and "rocks" below a level of about 675 feet. It is overlain in all three locations by a thick clay zone with relatively thin interlayers of water-bearing sand, capped by a thin hard ("rock") layer at a depth of 300 to 360 feet. This clay zone corresponds to the Plio-Pleistocene continental deposits (Page, 1977). Between 100 and 350 feet, the profile is still predominantly clay, but includes



**FIGURE 2-4 LOCATIONS OF DEEP WELLS AND BORINGS AT CASTLE AFB  
FOR WHICH DRILLERS' LOGS EXIST**



**FIGURE 2-10 BASE PRODUCTION WELL AND EXISTING TEST WELL LOCATIONS**

Table 2-2

Base Production Well Specifications  
Castle Air Force Base

Well	Year of Con- struc- tion	Total Depth (feet)	Casing Depth (feet)	Casing Perforation Intervals (feet)	Well Diameter (inches)	Original Well Capacity (gpm)	PG&E Well Efficiency Test May 1983 (gpm)
New PW	1984	804	734	261 - 730	18 telescoping to 14	5,300	ND
PW-1	1939	305	273	None	14	1,600	850
PW-2	1939	320	319.5	299 - 319.5	14	1,600	922
PW-3 <sup>1</sup>	1939	290	267	ND	14	1,600	806
PW-4	1939	290	270	ND	14	1,200	587
PW-5	1956	120	76	ND	8	35	ND
PW-6	ND	120	76	ND	8	35	ND
PW-7	1951	260	260	ND	14	500	ND
PW-8	1951	300	290	ND	16	1,200	ND
PW-9	1951	300	285	ND	16	1,200	ND
PW-11	1954	80	80	ND	10	25	ND

ND = No data.

Source: Castle AFB documents.

<sup>1</sup> Before well reconstruction in 1984 - 1985.

Table 2-3 lists the total annual water production by well and for the Base as a whole for the years 1979 through 1984. This information was obtained from documents supplied by the Base Civil Engineering Water Department. As indicated in this table, annual water production at CAFB ranges between 480 and 600 million gallons. Until 1981, the bulk of the water production was fairly evenly distributed between PW-1, PW-2, PW-3, PW-4, PW-7, and PW-8 in the Main Base and family housing systems. Between 1981 and 1984, in response to developing groundwater quality problems, production from PW-3, PW-4, and eventually PW-2 was phased out, so that in 1984 PW-1 provided approximately half of the total Base production, with the rest was divided between PW-7 and PW-8 primarily. Total annual production has generally remained below 3 million gallons from PW-5 and PW-6 combined, and below 0.5 million gallons for PW-11. There was no significant production from PW-9 between 1981 and 1984.

## 2.4.3.2 Existing on-Base Test Wells

In November 1981, CAFB contracted J. H. Kleinfelder and Associates to drill seven test wells, designated TW-12 through TW-18, in the shallow aquifer in order to delineate the extent of groundwater contamination in the Main Base area. Available well construction details are summarized in Table 2-4, and well logs for these wells are reproduced in Appendix D. The wells were drilled presumably by mud rotary methods to depths of 95 to 100 feet, ending in clay in six out of seven holes. The wells appear to be constructed of 4-inch PVC ending with 10 feet of screen, equipped with dedicated electrical submersible pumps suspended on 1-inch PVC drop-pipe near the bottom of the screen and capped with air-tight well seals at the surface. According to ESI (1983), the annulus was grouted to at least 20 feet below ground surface in all seven wells. Threaded access holes are provided in the well seals for measurement of water levels. These wells have been used for routine monitoring of trichloroethylene since late 1981. Samples are collected by personnel from the Base Bioenvironmental Engineer's office. The procedure is to purge the well for a few minutes, pumping at a rate of 30 gpm in those wells that can sustain such a high yield. The sample is then collected from a low-flow sampling port branched into the main discharge line.

ESI (1983) referred to an eighth test well, TW-19, reportedly located in the WSA area, but did not provide any data on well construction.

Table 2-3

Annual Water Production Rates  
Castle Air Force Base  
(in millions of gallons)

Year	Production Well Number										Total
	1	2	3	4	5	6	7	8	9	11	
1979	87.9	76.3	86.8	100.6	2.5	0.7	77.4	112.5	0	0.1	544.8
1980	67.7	95.9	95.1	87.2	2.0	1.7	90.8	128.0	0	0.1	568.5
1981	147.4	158.6	6.6	79.2	1.3	1.3	81.6	125.5	0	0.3	601.8
1982	103.1	104.0	0	74.1	1.0	1.1	78.6	111.8	0	0.3	474.0
1983	134.8	133.8	18.9	47.7	0.4	2.0	96.6	49.1	0	0.2	483.5
1984	243.5	23.6	1.4	0.6	0.8	1.9	113.5	102.5	0	0.4	488.2

Source: Castle Air Force Base documents.

Table 2-4

Test Well Specifications  
Castle Air Force Base

Well	Total Depth (feet)	Length of Well Screen (feet)	Well Diameter (inches)	Well Capacity <sup>1</sup> (gpm)
TW-12	97	10	4	30
TW-13	90	10	4	30
TW-14	92	10	4	30
TW-15	82	10	4	30
TW-16	102	10	4	<10
TW-17	100	10	4	<10
TW-18	89	10	4	30
TW-19	77	Unknown	8	> 5

<sup>1</sup>Measured in this investigation during sampling.

Upon inquiry, TW-19 turned out to be an abandoned production well, approximately in line with PW-5 and PW-6, and presumably installed at the same time and in the same manner as these wells. It has an 8-inch steel casing, and was sounded in December 1984 to a depth of 77 feet below ground surface (the reported casing depth in PW-5 and PW-6 is 76 feet). The old turbine pump was removed from this well in 1982 or 1983, and the casing was cut down to about 1 foot above ground level and capped-off by Base Civil Engineering. No water quality data were available for this well in the Base documents provided, although a sample was reportedly taken in 1982 or 1983.

The locations of all existing test wells on-Base are shown in Figure 2-10.

#### 2.4.3.3 Off-Base Wells

A detailed inventory of off-Base wells was beyond the scope of this investigation, although some preliminary information has been obtained from the Phase I report and additional sources. Off-Base groundwater users can be divided into three groups: the Merced Irrigation District, the City of Atwater, and residential users.

The Merced Irrigation District (MID) currently operates approximately 240 wells and a network of irrigation drains and canals throughout central Merced County and surrounds CAFB on the east, southeast, and southwest. Of the 240 wells, 158 were drilled in the 1920's to 1940's, and are approximately 80 to 100 feet deep. They include approximately 13 "irrigation wells," which are open bottom and cased with solid (nonperforated) pipe, and 145 "drainage wells," which are perforated within 20 to 30 feet of ground surface, and serve to dewater saturated sediments above the shallow clay. Another 80 "project wells" were installed in the late 1960's to depths of 180 to 300 feet and deeper, and were constructed of open-bottom solid (nonperforated) pipe. The drainage wells are pumped in the spring and summer to alleviate water-logging of shallow soils, and discharge into the canal system where the water is used for irrigation on an as-needed basis. The irrigation and project wells are pumped in drought years to supplement the surface water supply for irrigation. At least six MID wells are located within 1,000 feet of the CAFB boundary.

The City of Atwater currently has 10 production wells on-line according to the Public Works Engineer (Silva, 1985, personal communication). They range in total depth from 158 feet (unconfirmed) to 320 feet, indicating that they draw water from the confined aquifer. Reported yields range from 1,000 to 2,400 gpm. The nearest Atwater city well is approximately 1 mile southwest of CAFB.

There are numerous residential wells located on properties surrounding the Base, including three wells in the Castle Mobile Home Park just beyond the main gate, between CAFB and Castle Gardens family housing. Of seven residential wells inventoried by ESI (1983) immediately adjacent to the southwest Base boundary, total depths ranged between 60 and 140 feet, indicating that they draw water from the shallow aquifer.

#### 2.4.4 Groundwater Quality

Groundwater above the base of freshwater in the vicinity of CAFB has been characterized as calcium-sodium-bicarbonate and sodium-calcium-bicarbonate water; that is, water in which bicarbonate amounts to 50 percent or more of anions in milliequivalents per liter (meq/L), and sodium and calcium are first or second in order of abundance of cations, but neither is 50 percent or more in meq/L. Hardness in groundwater in the immediate vicinity of CAFB is generally less than 120 mg/L (as  $\text{CaCO}_3$ ), and local groundwater has been characterized as being of good chemical quality (Page, 1977). Table 2-5 gives background ranges for selected chemical parameters in the three major hydrogeologic units distinguished beneath CAFB, based on analyses from 20 wells in the area reported by Page (1977). Based on these data, there are little or no significant differences in inorganic water quality between the three units.

Of particular interest is nitrate, which was sampled at CAFB in this investigation. Page reported concentrations of nitrate as nitrogen in groundwater ranging between 1.3 and 6.8 mg/L. The corresponding range for nitrate (reported as nitrate) would be 5.8 to 29 mg/L.

Table 2-5

Range of Concentrations for Selected Chemical  
Parameters in Wells in the Merced-Atwater Area

Parameter	Range of Concentration <sup>1</sup>				Mehr- ten Forma- tion
	Shallow Aquifer		Confined Aquifer		
Specific conductance (umho/cm)	162 -	438	275 -	495	285
pH	7.3 -	8.8	7.6 -	8.0	8.0
Temperature (°C)	19 -	21.5	21		---
Dissolved nitrate (mg/L)	1.3 -	6.8	1.6 -	3.2	3.4
Dissolved lead (mg/L)	0.005		<0.005 -	0.008	---
Dissolved iron (mg/L)	<0.0002 -	0.002	<0.020		---
Dissolved manganese (mg/L)	<0.010 -	0.015	<0.050		---
Dissolved calcium (mg/L)	16 -	42	23 -	48	22
Dissolved magnesium (mg/L)	5.4 -	16	7.7 -	19	10
Dissolved sodium (mg/L)	6.2 -	27	23 -	38	20
Bicarbonate (mg/L)	48 -	196	134 -	244	126
Chloride (mg/L)	2.5 -	15	8.1 -	36	11
Dissolved nitrate, as nitrogen	2.7 -	4.5	1.3 -	6.8	3.4
Dissolved nitrate and nitrite, as nitrogen	0.8 -	5.3	1.6 -	5.2	---

<sup>1</sup>From 20 selected wells, reported by Page (1977); only one well available in the Mehrten Formation.



According to ESI (1983), Base water supply sources and test wells have been monitored for organic compounds and selected metals since 1980 or 1981. The compounds detected and the range of concentrations reported by ESI were the following:

---

Trichloroethylene (TCE)	ND - 0.136 mg/L
Trans-1,2-dichloroethene	ND - 0.0093 mg/L
Carbon tetrachloride	ND - 0.0004 mg/L
Chloroform	ND - 0.0011 mg/L
Dibromochloromethane	ND - 0.0015 mg/L
Bromoform	ND - 0.0026 mg/L
Bromodichloromethane	ND - 0.0004 mg/L
Methylene chloride	ND - 0.0005 mg/L
Arsenic	ND - 0.014 mg/L

---

ND = Not detected.

Trichloroethylene (TCE) has been the only organic compound detected consistently in the test wells and several of the production wells. As a result, the Base has instituted frequent monitoring specifically for TCE. Samples are collected weekly from the production wells and quarterly from the test wells. The results of groundwater sample analyses for TCE have been summarized from Base documents in Tables 2-6 for the Base production wells and 2-7 for the test wells.

Production wells PW-5, PW-6, PW-7, PW-8, PW-9, and PW-11, when sampled, have not exhibited detectable levels of TCE. Of the Base production wells, PW-3 has consistently exhibited the highest levels of TCE, ranging from nondetected to 0.043 mg/L. During 1984, TCE concentrations in PW-3 commonly ranged between 0.012 and 0.020 mg/L. Of the other production wells, PW-2 has exhibited the next highest levels (nondetected to 0.0221 mg/L), followed by PW-4 (0.0016 to 0.019 mg/L). PW-1 generally remained at trace (<0.0004 mg/L) or nondetectable levels until late 1983, and has since ranged up to 0.0115 mg/L.

It should be noted that TCE did not begin showing up at significant levels in PW-1 until it became the prime producer for the Main Base system in late 1983 (Table 2-3), and had presumably altered the groundwater gradient, thus inducing TCE flow into this well.

All seven test wells sampled (TW-12 through TW-18) are finished in the shallow aquifer. Of these, only TW-12 has never exhibited TCE concentrations above trace levels. In general, TW-16 has exhibited the highest levels of TCE, ranging from 0.0356 to 0.136 mg/L. No clear seasonal or long-term trend is apparent in the data reported in Table 2-7.

In cooperation with the Merced County Health Department, CAFB routinely samples water in the three Castle Mobile Home Park (CMHP) wells and eight off-base residential wells. Data available in ESI (1983) and Base documents indicate that TCE concentrations in the CMHP have ranged from nondetected to 0.0048 mg/L. Of the eight residential wells, only two have exhibited significant levels: one at 4841 Bellevue opposite the contractor's gate (nondetected to 0.0087 mg/L), and one at 4781 Santa Fe just outside Base gate No. 2 (nondetected to 0.024 mg/L). In both wells, TCE concentrations peaked in 1981 - 1982 and have declined since early 1983.

Table 2-6

Summary of TCE Concentration Data for Castle Air Force Base Production Wells  
1978 - 1984, in mg/L

Sampling Date	Well Number										Labl
	PW-1	PW-2	PW-3	PW-4	PW-5	PW-6	PW-7	PW-8	PW-9	PW-11	
10 March 1978	<0.0015	<0.0015		0.0033					<0.0015		
28 March 1978	<0.0015	<0.0015	0.0036	0.0016					<0.0015		
28 June 1978	<0.0015	<0.0015	0.0047	0.0023				<0.0015		<0.0015	
25 February 1980		<0.0010	0.0041	0.0016	<0.0010	<0.0010	<0.0010	<0.0010		<0.0010	H
18 March 1980	<0.0005	<0.0005	0.0007	0.0057	<0.0005	<0.0005	<0.0005	<0.0005		<0.0005	C
23 October 1980			0.0160	0.0070							
23 October 1980	TR <sup>2</sup>	0.0012	0.0119	0.0066	TR	TR	TR	TR		TR	
12 January 1981	<0.0005	0.0043	0.0305	0.0064	<0.0005	<0.0005	<0.0005	<0.0005			
9 June 1981	TR	0.0086	0.0161	0.0076	ND	ND					
13 July 1981	0	0.0073	0.0099	0.0040	ND	ND					
10 August 1981	TR	0.0119	0.0464	0.0086	ND	ND	TR	ND		ND	
31 August 1981		0.0221	0.0221	0.0076							
15 September 1981	TR	0.0092	0.0181	0.0052							
13 October 1981	TR	0.0085	0.0143	0.0067							
10 November 1981	TR	0.0075	0.0119	0.0051							
23 November 1981			0.0101								
7 December 1981	0.0064	0.0072	0.0038	0.0024							
14 December 1981			0.0054								
19 January 1982	TR	0.0067	0.0078	0.0036							
8 February 1982	0.0002	0.0085	0.0124	0.0051	ND	ND	ND	ND		ND	
17 March 1982	TR	0.0062	0.0073	0.0025							
13 April 1982	TR	0.0067	0.0018	0.0041							
18 May 1982	TR	0.0043	INOP	0.0035							
9 June 1982	TR	0.0077	INOP	0.0058							
20 July 1982	TR	0.0050	INOP	0.0070							
14 September 1982	TR	0.0048	INOP	0.0058							
13 October 1982	TR	0.0040	INOP	0.0082							
17 November 1982	TR	0.0052	INOP	0.0040							
12 January 1983	TR	0.0037	INOP	0.0064							
9 February 1983	ND	0.0078	INOP	0.0091	ND	ND	ND	INOP		ND	
15 March 1983	TR	0.0072	INOP	0.0108							

When not specified, analytical laboratory is OEH, Brooks Air Force Base. Others: H = State Health Lab,  
C = California Water Labs, Inc., W = WESTON Labs.

2TR = trace; ND = not detected; INOP = well inoperative.

Table 2-6  
(continued)

Sampling Date	PW-1	PW-2	PW-3	PW-4	Well Number PW-5	PW-6	PW-7	PW-8	PW-9	PW-11	Lab
4 April 1983	TR	0.0028	INOP	0.0095	ND	ND	ND	ND			
18 May 1983	TR	0.0127	0.0301	0.0170	ND	ND	ND	ND			
13 June 1983	0.0003	0.0128	ND	0.0154							
12 July 1983	0.0003	0.0109		0.0109							
9 August 1983	0.0004	0.0110	0.0197	0.0138							
6 September 1983	0.0004	0.0115	0.0168	0.0159							
24 October 1983	0.0023	0.0148	0.0430	0.0136							
2 November 1983	0.0106	ND	0.0390								
13 December 1983	0.0003	0.0078	0.0200	0.0079							
10 January 1984	0.0005	0.0103	0.0044	0.0105	ND	INOP	ND	ND	<0.0002	ND	W
30 January 1984	0.0022	0.0111	0.0222	0.0155							
28 February 1984		0.0040		0.0080							
6 March 1984	0.0039	0.0091	0.0165	0.0111							
9 April 1984	ND	0.0037	0.0158	0.0110							
15 May 1984	0.0038	0.0043	0.0120	0.0087							
5 June 1984	0.0058	0.0070	0.0032	0.0089							
10 July 1984	0.0015	0.0073	0.0160	0.0092							
1 August 1984	0.00733	0.00835	0.01699	0.01261							
7 August 1984	0.0050	0.0061	ND	0.0190							
14 August 1984	0.00675	0.00830	0.01867	0.01407							
24 August 1984	0.00789	0.00749	0.01737	0.01266							
5 September 1984	0.00750	0.00755	0.01539	0.01230							
5 September 1984	0.0006	0.0076	0.0172	0.0117							
11 September 1984	0.00775	0.00809	0.01685	0.01202							
18 September 1984	0.00816	0.00789	0.02189	0.01745							
25 September 1984	0.00711	0.00909	0.01924	0.01526							
2 October 1984	0.00374	0.01032	0.01774	0.01283							
9 October 1984	0.00558	0.00604	0.01820	0.01584							
16 October 1984	0.01154	0.01111	0.01955	0.01629							
23 October 1984	0.00528	0.01084	0.01995	0.01695							
30 October 1984	0.00792	0.00890	INOP	INOP							
6 November 1984	0.00340	0.00890	INOP	INOP							
14 November 1984	0.00879	0.00836	INOP	INOP							
20 November 1984	0.00702	0.00671	INOP	INOP							
27 November 1984	0.00962	0.00964	INOP	INOP							

When not specified, analytical laboratory is OEH, Brooks Air Force Base. Others: H = State Health Lab,  
C = California Water Labs, Inc., W = WESTON Labs.

2TR = Trace; ND = not detected; INOP = well inoperative.



Table 2-7

Summary of TCE Concentration Data for Castle Air Force Base  
Test Wells, 1981 - 1984, in mg/L<sup>1</sup>

Sampling Date	Well Number						
	TW-12	TW-13	TW-14	TW-15	TW-16	TW-17	TW-18
23 November 1981	TR <sup>2</sup>	0.0215	0.0280	0.0272	0.0587	0.0076	0.0024
14 December 1981	--	0.0189	0.0233	0.0187	0.0574	0.0079	0.0016
8 February 1982	ND	0.0270	0.0490	0.0180	0.120	0.0077	0.0030
18 May 1982	TR	0.0220	0.0310	INOP	0.055	0.0058	0.0033
18 August 1982	ND	0.0183	0.0328	INOP	0.0367	0.0061	0.0041
17 November 1982	ND	0.0185	0.0174	INOP	0.060	0.0077	0.0043
9 February 1983	ND	0.0289	0.0962	0.0166	0.0356	0.0130	0.0058
18 May 1983	ND	0.0339	0.0680	0.0185	0.1360	0.0194	0.0058
9 August 1983	ND	0.0253	0.0665	0.0150	0.095	0.0091	0.0073
2 November 1983	ND	0.0266	0.0658	0.0141	0.0774	ND	0.0094
30 January 1984	ND	0.0372	0.0690	0.0138	INOP	INOP	0.0183
15 May 1984	ND	0.0190	0.0480	0.0088	0.0410	INOP	ND
7 August 1984	ND	ND	ND	0.0590	INOP	INOP	ND

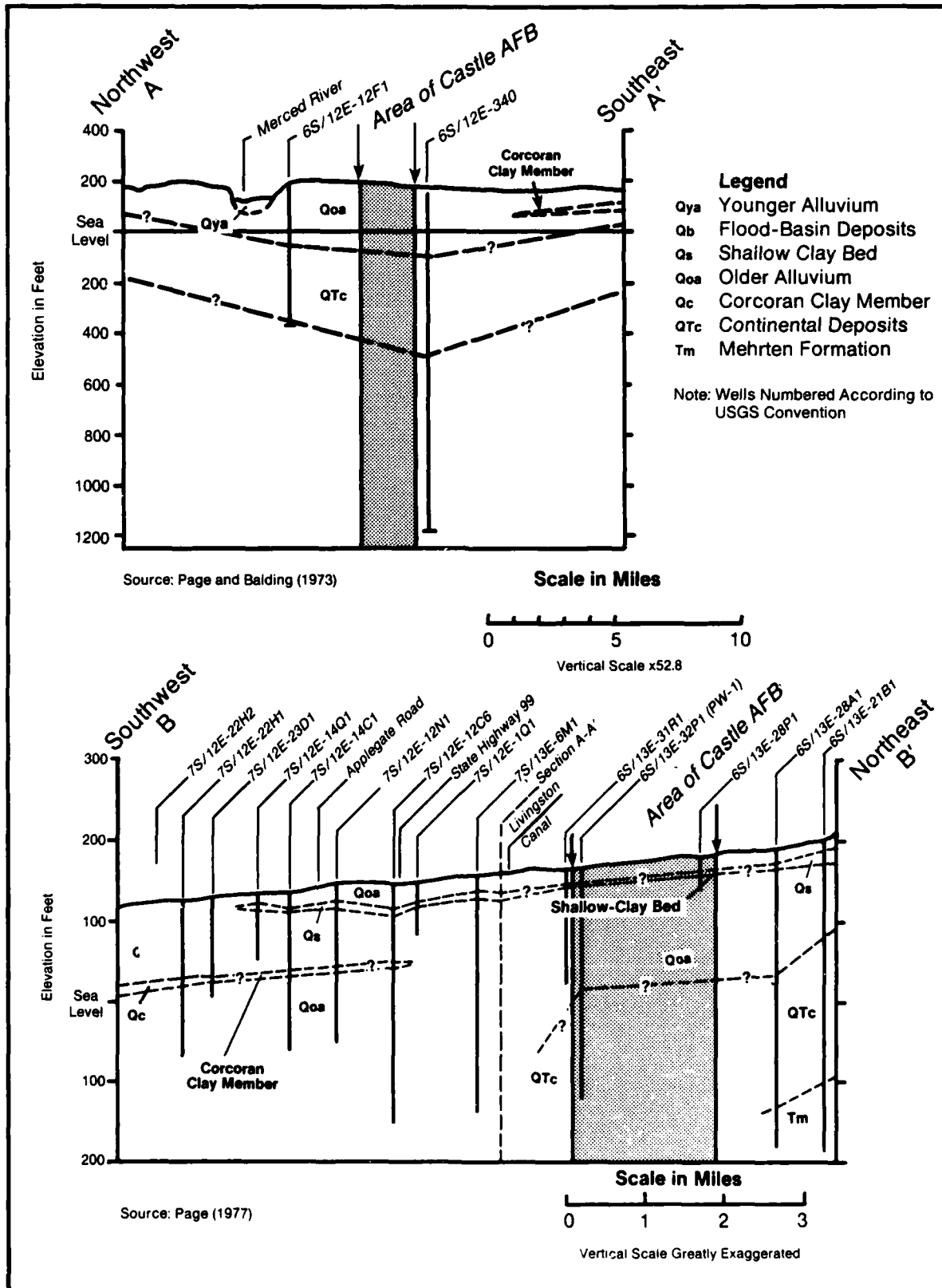
<sup>1</sup>All samples analyzed by OEHL, Brooks Air Force Base.<sup>2</sup>TR = trace; ND = not detected; INOP = well inoperative.

some hard, shaly clays and siltstones, and thicker sand interlayers. The transition to Pleistocene older alluvium is not clear, but apparently occurs within this zone. A gravel zone 15 to 25 feet thick occurs consistently in all 3 borings between approximately 65 and 90 feet. The gravel is overlain by interlayered sand and clay to the surface, including a thick sand layer between 15 and 50 feet below ground surface in the area of PH-2.

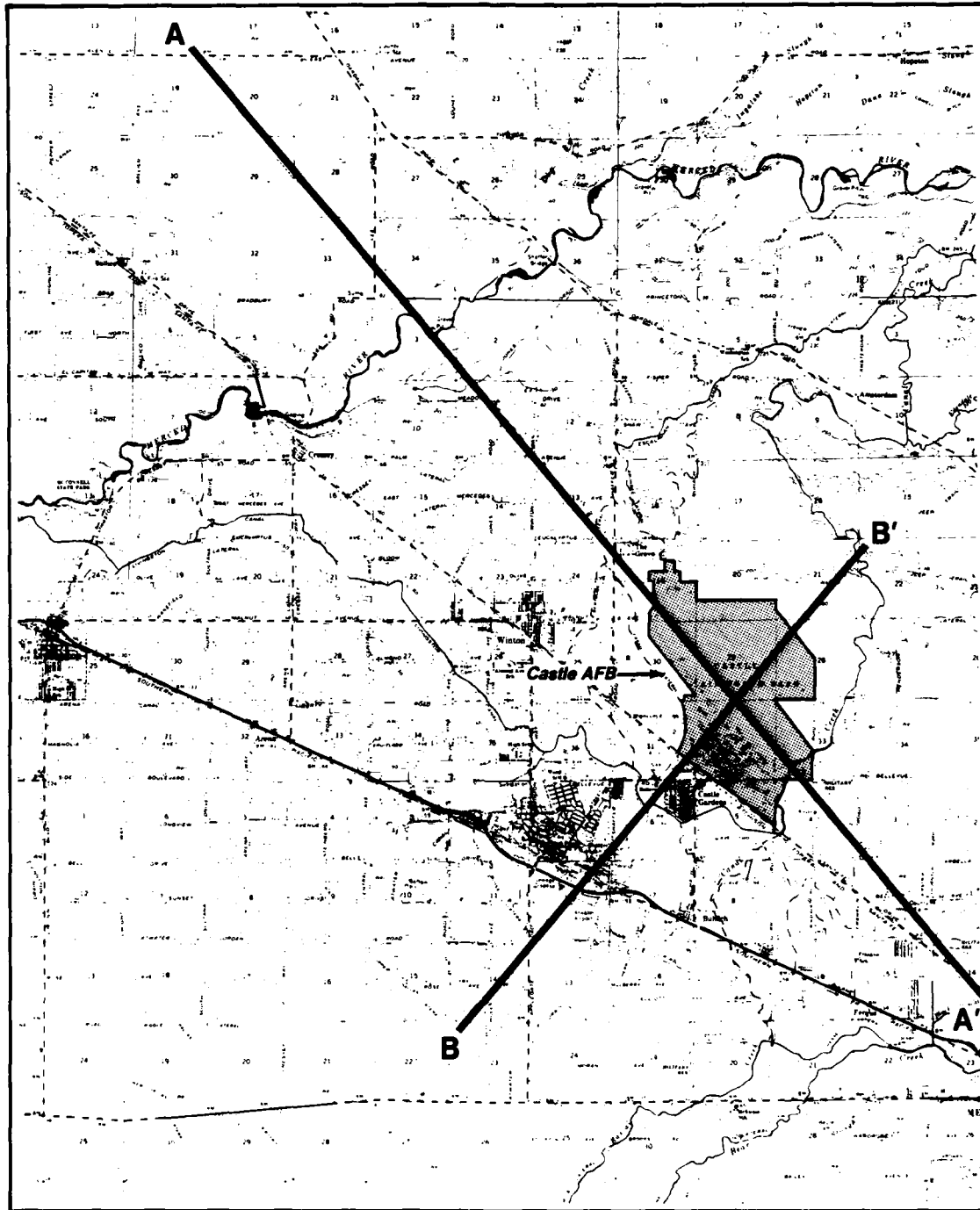
Additional detail on the shallow subsurface in the Main Base Sector is given in the well logs for PW-1 through PW-4 in Figure 2-6. These wells are open to a water-bearing sand at 285 to 300 feet. This sand is overlain by interlayered hard and soft clays, with a few thin water-bearing sand interlayers, up to a depth of approximately 90 feet. A coarse gravel layer is found consistently between approximately 65 and 90 feet, generally overlain by water-bearing sand between 35 and 65 feet. Surface sediments generally consist of "surface sand" and hardpan, although a substantial sandy clay layer occurs in PW-4 between 15 and 40 feet. However, the shallow clay reported by Page (1977) as probably occurring continuously beneath CAFB between depths of 15 and 35 feet is not found consistently in these well logs. Further detail on shallow subsurface geology (down to 100 feet) in the Main Base area can be obtained from the geology logs for existing test wells 12 through 18, provided in Appendix D. In general, these logs support the general description given here; further discussion of shallow subsurface geology is provided in Section 4.

The reasonably consistent subsurface profile in the Main Base Sector can be contrasted with the well log for PW-5, in the East Sector (Figure 2-6). There, the shallow profile is much more heterogeneous, consisting primarily of interlayered clays with relatively thin (less than 9 feet) sand and gravel zones down to 80 feet. The casing bottom is seated in hard brown clay, and the open hole below most likely consists of relatively competent clays with significant water-bearing sand interlayers. The relative heterogeneity of the shallow subsurface sediments encountered in the East Sector correlates well with the transition zone between older alluvium and continental deposits identified between depths of 100 and 350 feet in the Main Sector (Figure 2-5).

Figure 2-7 includes two cross-sections through the area of CAFB taken from Page and Balding (1973) and Page (1977). The areas of the cross-section and the well locations are given in Figure 2-8. Further discussion of the subsurface geology at CAFB and current interpretations and correlations are given in Section 4, where they are supplemented by the findings of this investigation.



**FIGURE 2-7 GEOLOGIC CROSS-SECTIONS THROUGH THE AREA OF CASTLE AFB**



Scale in Miles  
0 1 2



**FIGURE 2-8 LOCATION MAP FOR GEOLOGIC CROSS-SECTIONS**

## 2.4 HYDROGEOLOGY

### 2.4.1 Hydrogeologic Units

Subdivision of the vertical profile in the vicinity of CAFB into distinct hydrogeologic units is based primarily on known zones of high well yield. In the South and Main Base Sectors of CAFB and in areas to the east and south, two principal units, a shallow and a confined aquifer, have been identified and are commonly used for drinking water supply and irrigation purposes. Recently, the Base drilled a new production well that taps a third, deeper water-producing unit. In this report, the following terminology will be used to distinguish the three major water-producing zones: deep aquifer, confined aquifer, and shallow aquifer. Although there is insufficient hydrologic evidence to confirm that these units are, in fact, hydraulically distinct, the geologic evidence indicates that they are separated by significant thicknesses of clayey sediments.

The deep aquifer comprises the productive zones of the Mehrten Formation and the base of the continental deposits, and occurs beneath CAFB below depths of 650 to 675 feet. It has a thickness of about 500 feet, ranging down to the base of freshwater at about 1,200 feet. It is considered an important aquifer in the Modesto-Merced area. In test results reported by Page and Balding (1973) from other parts of the San Joaquin Valley, the Mehrten exhibited hydraulic conductivities of 0.01 to 67 feet per day, and well yields ranged from 1,320 to 2,100 gpm. The new production well at CAFB is perforated in both the deep and confined aquifers. It was initially tested at 5,300 gpm, and has a sustained yield of 3,500 gpm. The bulk regional transmissivity of the Mehrten was reported by Page and Balding (1973) as 9,100 square feet per day.

The family housing and older Main Base supply wells all produce from a zone between 265 and 350 feet, corresponding to the confined aquifer identified by Page (1977), consisting of interlayered clays and sands, and including some moderately indurated shaly and siltstone layers. This aquifer is in the transition zone between older alluvium and continental deposits. According to Page and Balding (1973), this is the most extensively developed aquifer in the Modesto-Merced area. Well yields average 1,900 gpm and range up to 4,450 gpm. Specific capacities, correlating roughly with transmissivities, tend to increase from east to west, from older to younger, thicker sediments.

The shallow aquifer consists of the sand and gravel zone identified in Figures 2-5 and 2-6, which in the CAFB Main Base Sector occurs between 35 and 90 feet, and includes a significant (over 15 feet) thickness of coarse stream gravel in its lower portion. Page (1977) called this the "intermediate aquifer," separated from the confined aquifer by the Corcoran clay. His interpretation showed the Corcoran clay pinching out southeast of CAFB, so that beneath the Base the intermediate and confined aquifers would be in hydraulic contact, responding as a single aquifer. Background information and field data gathered in this investigation suggest that, in fact, they are distinct aquifers beneath the Main Base, separated by 150 to 200 feet of clayey sediments.

Page (1977) hypothesized that a shallow aquifer existed above a continuous clay layer extending as a continuous layer beneath the Base at depths of 15 to 35 feet. The presence of such a shallow aquifer could not be confirmed in this investigation. Due to the discontinuity of the shallow clay (Subsection 2.3.3), however, shallow saturated zones could occur only as locally perched layers above the principal shallow aquifer, which may be locally confined beneath the shallow clay.

## 2.4.2 Regional Hydrogeology

CAFB is located in the east-central side of the San Joaquin groundwater basin. The primary source of natural recharge to the basin occurs from direct precipitation and runoff infiltrating the outcrop areas of the Mehrten Formation and the overlying unconsolidated deposits in the foothills and high terraces east of the Base. Recharge from direct precipitation on the valley floor is hampered by the very high evapotranspiration rate and the presence of hardpan in many of the native soils, which acts as a barrier to vertical infiltration.

An important secondary source of recharge in the region is from irrigation. In the Atwater-Merced area, sources of irrigation water are primarily surface water reservoirs formed by damming of streams in the Sierra Nevada foothills to the east. Water from these sources is conveyed to the valley floor in spring, summer, and fall through natural and man-made channels (e.g., Canal Creek, Escaladian Canal), and is applied as irrigation to the agricultural lands east and southeast of the Base. According to Page and Balding (1973) and Page (1977), groundwater sources are used primarily for back-up in dry years. Infiltration rates in the area are relatively slow, and some water-clogging of soils has occurred above the shallow clay layer identified by Page (1977). To remedy this, the Merced Irrigation District has installed a network of drainage wells which pump from these very shallow, or perched, zones into surface drains (Subsection 2.4.3.3).

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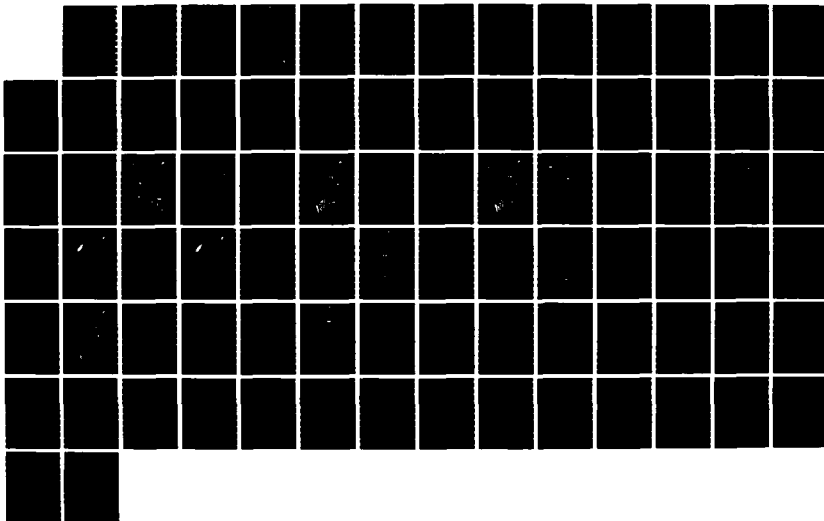
INSTALLATION RESTORATION PROGRAM PHASE II  
CONFIRMATION/QUANTIFICATION STA. (U) WESTON (ROY F) INC  
WEST CHESTER PA A L DUNN ET AL. 28 JUN 85  
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MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

The shallow aquifer consists of the sand and gravel zone identified in Figures 2-5 and 2-6, which in the CAFB Main Base Sector occurs between 35 and 90 feet, and includes a significant (over 15 feet) thickness of coarse stream gravel in its lower portion. Page (1977) called this the "intermediate aquifer," separated from the confined aquifer by the Corcoran clay. His interpretation showed the Corcoran clay pinching out southeast of CAFB, so that beneath the Base the intermediate and confined aquifers would be in hydraulic contact, responding as a single aquifer. Background information and field data gathered in this investigation suggest that, in fact, they are distinct aquifers beneath the Main Base, separated by 150 to 200 feet of clayey sediments.

Page (1977) hypothesized that a shallow aquifer existed above a continuous clay layer extending as a continuous layer beneath the Base at depths of 15 to 35 feet. The presence of such a shallow aquifer could not be confirmed in this investigation. Due to the discontinuity of the shallow clay (Subsection 2.3.3), however, shallow saturated zones could occur only as locally perched layers above the principal shallow aquifer, which may be locally confined beneath the shallow clay.

## 2.4.2 Regional Hydrogeology

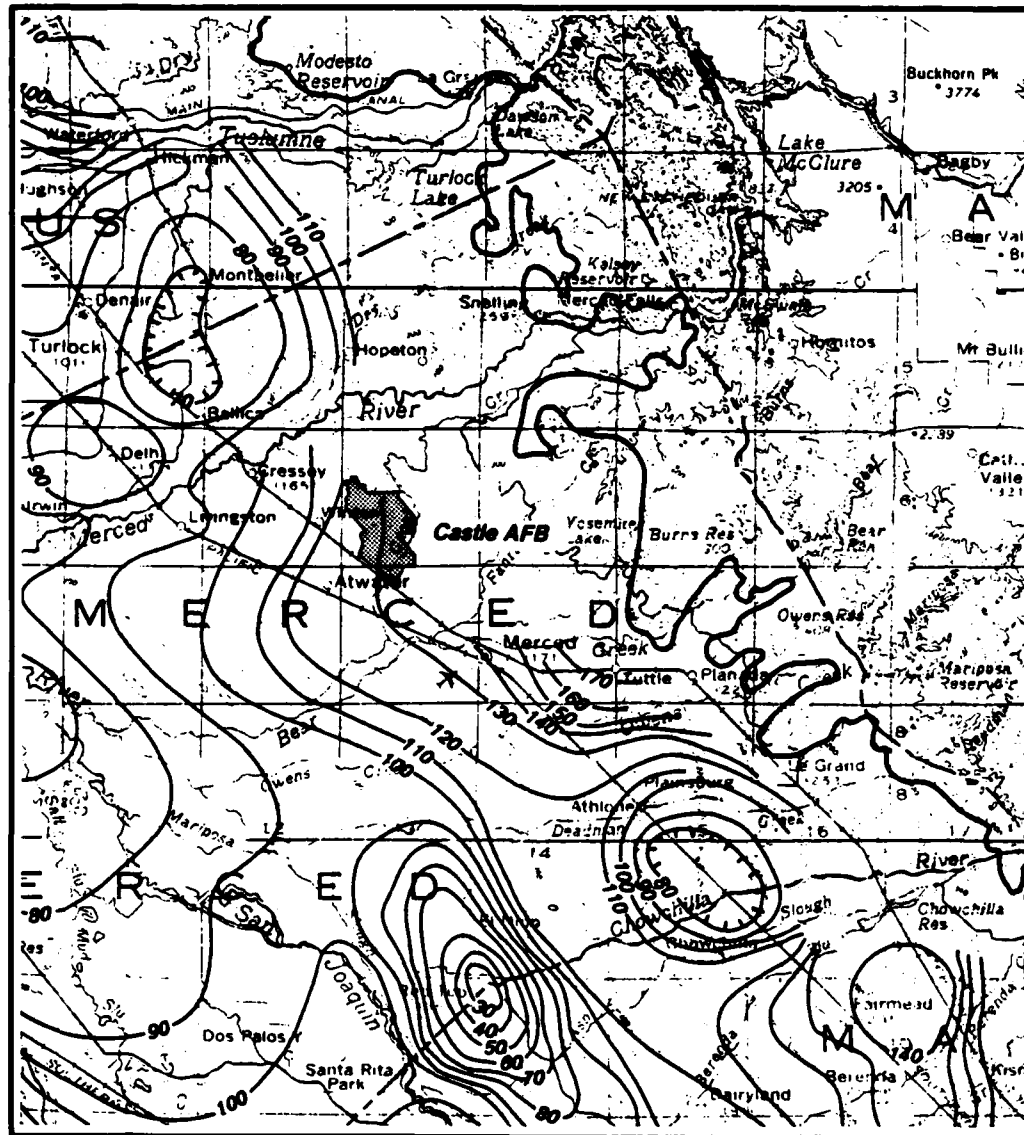
CAFB is located in the east-central side of the San Joaquin groundwater basin. The primary source of natural recharge to the basin occurs from direct precipitation and runoff infiltrating the outcrop areas of the Mehrten Formation and the overlying unconsolidated deposits in the foothills and high terraces east of the Base. Recharge from direct precipitation on the valley floor is hampered by the very high evapotranspiration rate and the presence of hardpan in many of the native soils, which acts as a barrier to vertical infiltration.

An important secondary source of recharge in the region is from irrigation. In the Atwater-Merced area, sources of irrigation water are primarily surface water reservoirs formed by damming of streams in the Sierra Nevada foothills to the east. Water from these sources is conveyed to the valley floor in spring, summer, and fall through natural and man-made channels (e.g., Canal Creek, Escaladian Canal), and is applied as irrigation to the agricultural lands east and southeast of the Base. According to Page and Balding (1973) and Page (1977), groundwater sources are used primarily for back-up in dry years. Infiltration rates in the area are relatively slow, and some water-clogging of soils has occurred above the shallow clay layer identified by Page (1977). To remedy this, the Merced Irrigation District has installed a network of drainage wells which pump from these very shallow, or perched, zones into surface drains (Subsection 2.4.3.3).

The regional direction of groundwater flow in the eastern San Joaquin Valley is to the west-southwest in all three principal hydrogeologic units. Under natural conditions, groundwater flows to the San Joaquin River and its major tributaries, and discharges as seepage to surface streams and as evapotranspiration from valley-bottom marshes. The regional groundwater level map in Figure 2-9 indicates that the Merced River west of CAFB acts as a groundwater drain or discharge area. In addition, two regional pumping centers act as groundwater discharge zones and significantly influence the direction of groundwater flow in the Atwater-Merced area: one north-northwest of CAFB and east of Turlock, centered in Montpelier; and another, combining two pumping centers, south-southeast of CAFB, centered near El Nido. Estimated total groundwater pumpage in the Atwater-Merced area, including the City of Merced and the Merced Irrigation District (MID), ranged between 47,000 and 120,000 acre-feet per year in the period from 1963 through 1973 (Page, 1977). Most of the groundwater pumping in the area is from the shallow and confined aquifers, with minimal contribution from the Mehrten or deep aquifer.

Groundwater levels in the area respond primarily to pumping and irrigation schedules, rather than to natural precipitation patterns (Page, 1977). Static water levels in the shallow and confined aquifers generally peak in spring (March or April), and may fluctuate 14 to 18 feet seasonally. Differences between static and pumping levels in a well range from 20 to 45 feet.

The groundwater flow direction beneath CAFB was not well understood prior to this investigation. The groundwater contours given by Templin (1984) (Figure 2-9) indicate that the primary direction of flow in the shallow aquifer is to the west. Page (1977, Plate 3) showed a groundwater trough running along the east side of CAFB, with outflow to the northeast. ESI (1983), in the IRP Phase I report for CAFB, reported water level measurements from the existing test wells in the Main Base and South Sectors indicating that groundwater flow beneath the Base was to the northwest. Selection of monitor well locations for this investigation was based on the most site-specific data available from ESI (1983, Figure 3-12).



Source: Templin, 1984

Scale in Miles



**Legend**

- 120 — Groundwater Level Contour  
Showing Elevation of Water Level in  
Main Producing (Unconfined) Aquifer
- Boundary of San Joaquin Groundwater  
Basin



**FIGURE 2-9 REGIONAL GROUNDWATER LEVEL MAP**

### 2.4.3 Base Supply and Other Wells

#### 2.4.3.1 Base Supply Wells

The CAFB water distribution network is supplied entirely from on-Base groundwater sources. The network can be divided into four systems: the Main Base system, the family housing system, the weapon storage area (WSA) system, and the firing range system. Until early 1985, the Main Base (community) system consisted of four wells (PW-1, PW-2, PW-3, and PW-4) manifolded together and pumping into a 500,000-gallon elevated steel storage tank used to supply the main portions of the Base southwest and west of the flightline. In early 1985, the Base activated a new deep water supply well which had been drilled in March 1984 and had a tested yield of 5,300 gpm. In the future, the Main Base system will be supplied primarily from this well, and PW-1 through PW-4 will be used for back-up supply only. The family housing (community) system consists of three wells (PW-7, PW-8, and PW-9) located in the Castle Gardens family housing area to the southwest of the Main Base. PW-7 and PW-8 are manifolded together and can be used to supply both Castle Gardens and, through an interconnection, the Main Base elevated pressure tank; PW-9 is used for emergency back-up supply only. The WSA (noncommunity) system consists of two wells (PW-5 and PW-6) pumping into a 15,000-gallon elevated steel storage tank used to supply the weapon storage area. The firing range system consists of a single well (PW-11) used to supply a toilet facility at the firing range. Base production well locations are shown in Figure 2-10.

All Base production wells were reportedly installed by cable-tool methods and are open (unscreened) below the bottom of the casing. All available geologic logs for Base production wells are illustrated schematically in Figures 2-5 and 2-6. All available well construction data for the Base production wells are summarized in Table 2-2. Based on available geologic and well construction data, wells in the Main Base (PW-1 through PW-4) and family housing systems are open to the confined aquifer only, and wells in the WSA and firing range systems are open to the shallow aquifer only. The new production well is blank cased and grouted to 260 feet, perforated from 261 to 730 feet, and open below 730 feet. Therefore, it is open to both the confined and deep aquifers.



## SECTION 3

### FIELD PROGRAM

#### 3.1 PROGRAM DEVELOPMENT

Task Order 0002 was issued in response to the Phase II Presurvey Report. Twenty-six sites had been identified as potential contamination sources in the Phase I report for CAFB. Twenty-one of the potential source sites and one additional unranked site were grouped into 16 investigation sites (Table 1-2) addressed in this Phase II, Stage I, Problem Confirmation Study. The field program approved in the task order (Appendix B) is summarized in Table 3-1.

For the purposes of clarity and ease of discussion, the 16 investigation sites addressed in the Phase II program were grouped into five geographic sectors. The following text reviews first the general considerations pertaining to the selection of field methodologies, then the actual field investigations developed for each of the five sectors. Subsection 3.3 summarizes the field investigations as they were actually carried out, in accordance with the program outline presented in this subsection.

##### 3.1.1 General Considerations

The primary purpose of a Phase II confirmation stage investigation is to establish the presence or absence of contamination at a site. A secondary purpose is to provide supplementary information to the Phase I evaluation of the potential for contaminant migration from a site. These purposes dictated the general approach used in developing the proposed field program, which consisted of the use of ground penetrating radar (GPR), and magnetometer, surface soil sampling, shallow soil borings, the location and construction of lysimeters and deep monitor wells, and groundwater and surface water sampling.

##### 3.1.1.1 Surface Geophysical Surveys

A ground penetrating radar (GPR) and a magnetometer were used in the South and North Sectors at old landfill areas where sources of contamination, such as buried drums, were suspected of existing below the surface. The GPR and magnetometer were used in the Main Base Sector to establish the location of a former overflow discharge line. The GPR measures changes in electrical properties of subsurface materials, and can detect lithologic or chemical interfaces. Thus, it is a useful tool in remote sensing investigations of buried objects, for delineating zones of subsurface disturbance, and for directing further subsurface sampling.

Table 3-1

Summary of Field Activities

Sector	Site	Activity
1. Main Base	TCE plume	<ul style="list-style-type: none"> <li>● Perform pilot test operations on production well 3. Sample well once a week for long-term test period.</li> <li>● Install 3 monitor wells and sample. Perform well and groundwater elevation survey.</li> <li>● Collect samples from test wells 14, 16, and 18 and Base production wells 1, 2, 3, 7, and 8. Perform well and groundwater elevation survey.</li> </ul>
	Discharge Area 8 (DA-8)	<ul style="list-style-type: none"> <li>● Install 3 monitor wells and establish 3 permanent staff gage stations. Collect water samples from monitor wells and staff gage stations.</li> <li>● Collect bottom sediment core samples from each staff gage station.</li> <li>● Conduct a magnetometer and GPR survey of the area around Building 1550 to locate overflow pipe.</li> </ul>
	Discharge Area 5 (DA-5)	<ul style="list-style-type: none"> <li>● Collect 3 bottom sediment core samples from the drainage ditch.</li> </ul>
	Discharge Area 7 (DA-7)	<ul style="list-style-type: none"> <li>● Collect 6 shallow soil samples to depths of 0.5 feet, and composite into 3.</li> </ul>
	Discharge Area 3 (DA-3)	<ul style="list-style-type: none"> <li>● Collect two core samples of bottom sediments from the drainage ditch.</li> </ul>
	Discharge Area 6 (DA-6)	<ul style="list-style-type: none"> <li>● Collect water samples from test wells 13, 15, and 17 and Base production well 4.</li> </ul>

Table 3-1  
(continued)

Sector	Site	Activity
2. South	South Landfill Zone (SLFZ)	● Drill 4 soil borings at DA-1 (the Jet Engine Test Facility); collect soil samples.
		● Collect a groundwater sample from test well 12.
		● Install and sample 6 monitor wells, 2 lysimeters, and 6 staff gages, and sample. Perform well, staff gage, and groundwater elevation survey.
		● Conduct magnetometer and GPR survey of DP-3.
3. East	Fire Training Area 1 (FT-1)	● Install 3 monitor wells and 2 lysimeters. Sample wells and lysimeters. Perform well and groundwater elevation survey.
		● Sample production wells 5, 6, and 11 and test well 19.
	Landfill 3 (LF-3)	● Install 2 monitor wells and sample. Perform well and groundwater elevation survey.
4. North	North Landfill Zone (NLFZ)	● Install 4 monitor wells and 2 lysimeters. Sample wells and lysimeters. Perform well and groundwater elevation survey.
		● Conduct magnetometer and GPR survey of landfill 5.

Table 3-1  
(continued)

Sector	Site	Activity
5. West Flightline	West Landfill Zone (WLFZ)	● Install 4 monitor wells and sample. Perform well and groundwater elevation survey.
	PCB Spills 1-3 (PCB 1-3)	● Collect 6 shallow soil samples and composite into 3 composite samples.
	Fuel Spills 1-4 (FS 1-4)	● Install 1 monitor well and 4 lysimeters and sample. Perform well and groundwater elevation survey.
	Discharge Area 2 (DA-2)	● Install 1 monitor well and sample. Perform well and groundwater elevation survey.
	Discharge Area 4 (DA-4)	● Drill and sample 2 soil borings.
	Fire Training Area 3 (FT-3)	● Install 1 monitor well and lysimeter, and sample. Perform well and groundwater elevation survey.

### 3.1.1.2 Monitor Wells

Contamination discharged on or near ground surface would be expected to be found in highest concentrations in the soils and in the shallowest groundwater underlying a site. At sites where the source of contaminant discharge was diffuse, had been buried, or could not be accurately located, monitor wells were emplaced adjacent to and downgradient from the approximate source location to sample groundwater in the shallow aquifer for indicators of contamination. In order to collect samples representative of aquifer quality, wells were expected to average approximately 100 feet in depth, but were to be drilled to a depth sufficient to fully penetrate a shallow aquifer of coarse sand and gravel underlain by clay. The total drilled footage of 27 wells was not to exceed 2,700 feet. Wells were to be constructed of 4-inch diameter welded black iron pipe and completed in the saturated zone with wire-wound 0.020-inch stainless steel well screen, and packed in Monterey sand to a height of 5 feet above the top of the well screen to prevent entrainment of sediment into the well during pumping. They were to be sealed with 2 feet of bentonite pellets and grouted with a 6:1 dry weight mixture of Portland cement and bentonite powder to prevent leakage down into the well annulus from the surface. Each well was to be secured with a locking cap. All wells were to be developed to ensure they were clear of sediment and foreign material introduced during drilling to the extent practicable.

Most of the wells were to be drilled at locations presumed to be in the downgradient direction from the area of interest, based on the limited water table data available from the Phase I report and supporting references. At least one well was located upgradient from each of the following sites to provide background water quality data: West Landfill Zone, North Landfill Zone, South Landfill Zone, Fire Training Area 1, and Discharge Area 8. All wells were drilled within the CAFB boundary.

### 3.1.1.3 Lysimeters

The term lysimeter was used in the Task Order to describe very shallow (approximately 10 feet deep) monitor wells designed to intercept perched water on top of soil hardpan. In background sources, including the Phase I report, the CAFB area was reported to be underlain by a hardpan at varying depths in the shallow subsoil. Therefore, shallow lysimeters were to be installed above this hardpan to monitor for the presence of perched groundwater and for potential contamination in this perched groundwater. Lysimeters were to be constructed of 2-inch diameter threaded Schedule 40 PVC pipe. No more than 5 feet of factory-slotted, 2-inch diameter 0.020-inch slot PVC screen was to be installed in each lysimeter.

In accordance with the Task Order, the lysimeters were expected to average approximately 10 feet in depth, but were to be drilled until the hardpan was encountered, and finished just above the hardpan.

### 3.1.1.4 Soil Borings

At sites where potentially contaminated wastes were confirmed to have been discharged directly onto the ground surface, soil borings were drilled to sample the surface and shallow sub-surface soil. Samples were to be taken from 0 to 10 feet below surface or to the top of the hardpan, whichever was encountered first. Six soil borings were to be drilled, four at discharge area 1, and two at Discharge Area 4.

### 3.1.1.5 Surface Soil Sampling

Shallow hand surface samples were to be collected at sites where discharges to the ground surface were determined to have been potentially contaminated with relatively immobile constituents, such as pesticides, herbicides, and PCB's. In these areas, any potential contamination would most likely be found at or near the soil surface. The two sites involved were PCB spill area 1-3 (the CE storage area for transformers), and DA-7 (the pesticide/herbicide handling and storage area). Prior to development of the Phase II effort at the PCB spill area, Base personnel had made an initial cleanup effort. WESTON proposed to review the records of clean-up and to take soil samples for analysis from the bottom of the excavation at the end of the clean-up effort, to verify that cleanup was complete. At DA-7, the pesticide/herbicide storage area, shallow soil samples were to be taken at the 0 to 6-inch interval on the site of the old evaporation pond and in areas of frequent pesticide/herbicide handling.

### 3.1.1.6 Air and Soil Gas Monitoring

During all surface soil sampling, soil boring, and well drilling operations, either an HNu organic vapor photoionization detector or other organic vapor analyzer was to be used to monitor organic vapors emanating from the borehole. The instruments were used primarily for safety (Appendix F) and as a preliminary screening method for contamination in samples and drill cuttings.

The HNu portable photoionization detection unit operates on the principle of detection based on light-induced ionization of carbon-carbon or carbon-nitrogen double or triple bonds (alkenes, alkynes, nitrites, amines, and aromatics). It is particularly suited to the detection of volatile aromatic compounds such as benzene, toluene, ethylbenzene, xylenes, and chlorobenzenes. It is "blind" to those nonphotoionizable, volatile substances such as saturated alcohols, saturated amines, alkanes, and saturated fluorochlorocarbons. It is capable of detecting airborne hydrocarbons at the one part per million level. Prior to field use, it is calibrated in the laboratory against a set of hexane standards, so that readings obtained are measured with respect to hexane. For this reason, it is used to measure qualitative or relative degree of atmospheric contamination with organics. In the field, it is zeroed against ambient background atmospheric levels.

The organic vapor analyzer (OVA) is a hydrogen flame ionization detector, and is able to detect organic compounds in air in the parts per million range, in the presence of moisture, nitrogen oxides, carbon monoxide, and carbon dioxide. Before field use, the instrument is filled with hydrogen gas and the battery is charged. The instrument is factory calibrated to a methane in air standard, so that readings obtained are measured with respect to methane. In the field, it is zeroed against ambient background atmospheric levels.

### 3.1.1.7 Staff Gages, Surface Water, and Ditch Sediment Sampling Stations

Potential contamination of the Base drainage ditches in the Main Base and South Sectors was suspected to have occurred from at least four sites: DA-3 (the CE yard washrack), DA-5 (the aircraft washrack), DA-8 (an overflow pipe from Building 1550), and the South Landfill Zone (SLFZ). To assess the presence or absence of contamination at these sites, water and sediment sampling locations were to be established at various locations in the ditches.

A total of eight locations were to be sampled for ditch sediments. The locations were to be adjacent to or downstream from DA-3, DA-5, and DA-8. Sediment samples were to be collected in 2-foot long cores and subdivided into two subsamples each.

A total of nine surface water sampling locations were to be established and permanently marked with staff gages. Three locations were to be the same as the three ditch sediment locations for DA-8, and six were to be in the drainage ditches forming the boundary of the SLFZ at the southern end of the Base.

The analytes authorized to be sampled at each site are reviewed in Subsection 3.1.1.10.

#### 3.1.1.8 Elevation Surveys

To complete the hydrogeologic investigation, WESTON proposed to survey the elevations of all the monitor well casings with respect to an existing USGS benchmark, and to make two complete rounds of groundwater level measurements. The purpose of gathering these data was for flow analysis, primarily to confirm the presumed direction of contaminant migration.

#### 3.1.1.9 Groundwater Sampling

WESTON proposed sampling the 11 lysimeters, 27 new monitor wells, 8 existing test wells, and 11 Base production wells in two rounds to be performed at different groundwater level conditions. All wells were to be purged of at least three well volumes immediately prior to sampling. Monitor wells were to be purged using WESTON's stainless steel Grundfos Model No. SP2-10 submersible pump. Water samples were to be collected and preserved according to standard U.S. EPA groundwater sampling protocols for the analytes of interest. All water samples were to be analyzed on-site for pH, temperature, and specific conductance. Specific analytical protocols and rationale used in developing them are reviewed in Subsection 3.1.1.10.

### 3.1.1.10 Analytical Protocol

Based on the Phase I report, the key chemical parameters of potential concern at CAFB were found to be: the priority pollutant volatile organic compounds (VOA) and methyl ethyl ketone (MEK), oil and grease (O&G), and phenols. Total organic carbon (TOC) and total organic halogens (TOX) are considered by the USAF as good general indicator parameters for organic contamination, and were therefore included in the analytical protocol for this project as screening parameters. In addition, metals (including the Safe Drinking Water metals cadmium, chromium, lead, mercury, and silver), pesticides/herbicides (endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP/silvex), polychlorinated biphenyls (PCB's), and nitrates were considered to be of concern at some specific sites. The analytical protocol developed for the Phase II, Stage 1, Problem Confirmation Study described in this report is summarized in Table 3-2. A complete list of the U.S. EPA priority pollutant VOA compounds is given in Table 3-3.

All soil samples were to be collected only once. All water quality sampling stations, including groundwater stations (production wells, test wells, monitor wells, and lysimeters) and surface water stations (staff gage locations) were to be sampled twice in the period between well completion and the scheduled end of WESTON's technical effort in June 1985.

### 3.1.2 Site-Specific Considerations

Factors affecting program development in a specific sector or in a site within a sector are described in the following text.

#### 3.1.2.1 Main Base Sector

Several high priority sites are located in the Main Base Sector. Thus, a large portion of the field program was devoted to this sector. The sites in this sector include:

- TCE plume
- Discharge area 8 (DA-8)
- Discharge area 5 (DA-5)
- Discharge area 7 (DA-7)
- Discharge area 3 (DA-3)
- Discharge area 6 (DA-6)

Table 3-2

Analytical Protocol for Phase II, Stage 1  
Problem Confirmation Study  
Castle Air Force Base

Site	Potential Contamination	Medium	Analytes <sup>1</sup>
<u>Main Base Sector</u>			
1. TCE plume	Waste solvents	Groundwater	VOA, including MEK, O&G, phenols, TOX, TOC
2. DA-8	Waste solvents	Groundwater and surface water	VOA, O&G, TOX, TOC
		Ditch sediment	VOA
3. DA-5	Waste solvents, oils, fuel	Ditch sediment	VOA, O&G
4. DA-7	Pesticides and herbicides	Soil	Pesticides/herbicides
5. DA-3	Waste solvents, oils, pesticides, and herbicides	Ditch sediment	VOA, O&G, pesticides/herbicides
6. DA-6	Industrial wastes, including solvents, oils, fuels, metals, pesticides, and herbicides	Groundwater	VOA, including MEK, O&G, phenols, TOX, TOC, metals, nitrate, pesticides/herbicides
<u>South Sector</u>			
7. SLFZ	Waste solvents, oils, fuel, metal sludges, landfill leachate	Groundwater and surface water	VOA, including MEK, O&G, phenols, TOX, TOC, metals, nitrate, pesticides/herbicides
		Soil	VOA, O&G

Table 3-2  
(continued)

Site	Potential Contamination	Medium	Analytes <sup>1</sup>
<u>East Sector</u>			
8. FT-1	Waste fuel, solvents, oils	Groundwater	VOA, including MEK, O&G, phenols, TOX, TOC, nitrate
9. LF-3	Waste solvents, oils, fuel, landfill leachate	Groundwater	VOA, including MEK, O&G, phenols, TOX, TOC, metals, nitrate, pesticides/herbicides
<u>North Sector</u>			
10. NLFZ	Industrial chemicals, waste solvents, oils, fuel, landfill leachate	Groundwater	VOA, including MEK, O&G, phenols, TOX, TOC, metals, nitrates, pesticides/herbicides
<u>West Flightline Sector</u>			
11. WLFZ	Waste solvents, oil, fuel, landfill leachate	Groundwater	VOA, including MEK, O&G, phenols, TOX, TOC, metals, nitrate, pesticides/herbicides
12. PCB 1-3	PCB	Soil	PCB
13. FS 1-4	Waste fuel, solvents, oils	Groundwater	VOA, O&G, phenols, TOX, TOC

Table 3-2  
(continued)

Site	Potential Contamination	Medium	Analytes <sup>1</sup>
14. DA-2	Waste solvents, oils, fuel	Groundwater	VOA, including MEK, O&G, phenols, TOX, TOC
15. DA-4	Waste solvents	Soil	VOA
16. FT-3	Waste fuel, oils, solvents	Groundwater	VOA, including MEK, O&G, phenols, TOX, TOC, nitrate

<sup>1</sup>Metals include cadmium, chromium, lead, mercury, and silver. Pesticides/herbicides include: endrin, lindane, methoxychlor, toxaphene, 2,4-D, and 2,4,5-TP/silvex. VOA = U.S. EPA priority pollutant volatile organic compounds; MEK = methylethyl ketone; O&G = oil and grease by IR Method.

Table 3-3

List of Volatile Organic Halogenated and Aromatic  
Compounds Determined by EPA Methods 601 and 602,  
with Method Detection Limits

Compound	Method Detection Limits in Water <sup>1</sup> (mg/L)	Laboratory Detection Limits in Water (mg/L)
Chloromethane	0.00008	0.0010
Bromomethane	0.00118	0.0012
Dichlorodifluoromethane	0.00181	0.0018
Vinyl chloride	0.00018	0.0002
Chloroethane	0.00052	0.0005
Methylene chloride	0.00025	0.0002
Trichlorofluoromethane	---	---
1,1-Dichloroethene	0.00013	0.0002
1,1-Dichloroethane	0.00007	0.0001
Trans-1,2-Dichloroethene	0.00010	0.0001
Chloroform	0.00005	0.0001
1,2-Dichloroethane	0.00003	0.00002
1,1,1-Trichloroethane	0.00003	0.0001
Carbon tetrachloride	0.00012	0.0001
Bromodichloromethane	0.00010	0.0001
1,2-Dichloropropane	0.00004	0.0001
Cis-1,3-Dichloropropene	0.00034	0.0003
Trichloroethylene	0.00012	0.0001
Dibromochloromethane	0.00009	0.0001
1,1,2-Trichloroethane	0.00002	0.00005
Trans-1,3-Dichloropropene	0.0002	0.0002
2-Chloroethylvinylether	0.00013	0.0002
Bromoform	0.00020	0.0002
1,1,2,2-Tetrachloroethane	0.00003	0.00005
Tetrachloroethene	0.00003	0.00005
Chlorobenzene	0.00025	0.0003
1,3-Dichlorobenzene	0.00032	0.0003
1,2-Dichlorobenzene	0.00015	0.0002
1,4-Dichlorobenzene	0.00024	0.0002
Benzene	0.0002	0.0002
Toluene	0.0002	0.0002
Ethylbenzene	0.0002	0.0002

<sup>1</sup>Source: Federal Register, 40 CFR 49, 209 (26 October 1984)  
--- = Not determined.

Proposed actions for specific sites were:

- Conduct a series of pilot test operations on production well 3 (PW-3) located in the TCE plume area to determine whether or not interaquifer transfer of contaminants was occurring via the mechanism of down-casing leakage. WESTON also proposed collecting groundwater samples from PW-3 once a week for six weeks after the sequence of pilot test operations was completed.
- Pilot test operations to be conducted at PW-3 were:
  - Measure water level on existing test well 14.
  - Collect groundwater sample from PW-3 and TW-14. Analyze the groundwater sample for purgeable halocarbons and aromatics (using U.S. EPA Methods 601 and 602).
  - Terminate pumping on PW-3 and monitor MW-14 water levels for changes using an electric tape.
  - Remove turbine pump from PW-3, and run a gamma log and other down-hole geophysical logs in order to verify the intervals of major confining beds.
  - Select two 10-foot intervals, one at the upper end of the confining interval and one at the base of the confining interval, for test grouting.
  - Using a high-pressure down-hole tool perforate the casing in the two 10-foot intervals selected, and inject high-pressure grout through the perforations and into the formation to form a grout seal in the annular space outside the well casing.
  - Collect a groundwater sample from the base of the standing water column in the casing using a Kemmerer sampler and repeat this procedure after 48 hours. Analyze both water samples for purgeable halocarbons and aromatics (using U.S. EPA Methods 601 and 602).
  - Reinstall the turbine pump into the well after measuring the static water level using an electric tape.

- Restart the pump up to full, normal production capacity, while monitoring water levels in test well 14 for changes using an electric tape.
- Conduct a GPR and magnetometer survey in the area of DA-8 around Building 1550 to determine the location or confirm the existence of the former overflow discharge line connecting the drainage ditch with the building.
- Collect bottom sediment cores from drainage ditches at the three staff gage stations adjacent to and downstream from DA-8, at three locations in the drainage ditch adjacent to and downstream from DA-5, and at two locations in the drainage ditch adjacent to and downstream from DA-3.
- Collect six shallow soil samples by hand at DA-7 (the pesticide/herbicide storage area). The six samples were then to be composited into three samples for analysis.

In addition to these actions at specific sites, WESTON proposed to install five monitor wells in order to monitor groundwater in the Main Base area. The proposed depth of each of these wells was to be 100 feet. Two wells were to be located close to the southwest boundary of the Base, in the downgradient portion of the TCE plume. One well was to be located upgradient of DA-8 and two wells downgradient. The proposed well completion, surveying, and sampling procedures for these wells were to be accomplished following the general considerations discussed in Subsection 3.1.1.

The proposed analytical protocol for samples to be collected from this sector is presented in Table 3-2.

#### 3.1.2.2 South Sector

This sector corresponds to the South Landfill Zone, which encompasses seven potential source sites:

- Landfill 1
- Landfill 2
- DA-1
- DP-1
- DP-2
- DP-3
- DP-4

Actions proposed for specific sites were to:

- Conduct a GPR and magnetometer survey of DP-3 in landfill 1 on a broad survey grid to determine the outlines of the pit and confirm the presence or absence of buried drums.
- Drill four soil borings along the drainage swale from the jet engine test facility (Building 953) in DA-1 to sample subsurface soils for oil and grease contamination. Soil samples were to be collected continuously to the top of the hardpan or to 10 feet, whichever occurred first.
- Install six staff gages along the two drainage courses forming boundaries of the zone to the southeast and southwest to mark permanent reference points for future surface water sampling.

WESTON also proposed to install six monitor wells to sample the groundwater upgradient and downgradient from the SLFZ. Three wells were to encircle landfill 1 and three wells were to encircle landfill 2. The wells were expected to average approximately 100 feet in depth. Two lysimeters were proposed to be paired with the two downgradient monitor wells at landfill 1. The lysimeters were expected to average 10 feet in depth, but were to be drilled until a hardpan was encountered, if present. If the hardpan was not encountered, the hole was to be backfilled with the cuttings, and a new site selected in the same area, if possible.

Completion, surveying, and sampling procedures for the wells and lysimeters were accomplished following the general considerations reviewed in Subsection 3.1.1.

#### 3.1.2.3 East Sector

This sector includes Fire Training Area 1 (FT-1) and landfill 3 (LF-3). WESTON proposed to install three monitor wells (one upgradient and two downgradient), and two lysimeters (paired with the downgradient monitor wells) in the FT-1 area. WESTON proposed to install two monitor wells at LF-3, both downgradient from the landfill to determine the presence or absence of contamination in groundwater from the site. As before, the wells in the East Sector were expected to average 100 feet in depth and the lysimeters 10 feet in depth. The proposed completion, surveying, and sampling procedures for these wells and lysimeters were accomplished following the general considerations reviewed in Subsection 3.1.1.



#### 3.1.2.4 North Sector

This sector includes the North Landfill Zone (NLFZ), which encompasses four potential source sites:

- Landfill 5 (LF-5)
- Disposal Pit 7 (DP-7)
- Disposal Pit 8 (DP-8)
- Disposal Pit 9 (DP-9)

The specific action proposed for LF-5 was to conduct a GPR and magnetometer survey of the landfill area on a broad survey grid to determine the outlines of the landfill and the presence or absence of buried drums. WESTON also proposed to install four monitor wells and two lysimeters in order to evaluate the potential for groundwater contaminant migration from the site. One well was to be located in the presumed upgradient direction from the site, and three wells were to be located downgradient of the site. The two lysimeters were to be paired with two of the downgradient wells. The wells in this sector were expected to average 100 feet and the lysimeters 10 feet in depth. The proposed completion, surveying, and sampling procedures for these wells and lysimeters were accomplished following the general considerations reviewed in Subsection 3.1.1.

#### 3.1.2.5 West Flightline Sector

A large portion of the field program was devoted to this sector, which included the following investigation sites:

- West Landfill Zone (WLFZ)
- PCB Spills 1 through 3 (PCB 1-3)
- Fuel Spills 1 through 4 (FS 1-4)
- Discharge Area 2 (DA-2)
- Discharge Area 4 (DA-4)
- Fire Training Area 3 (FT-3)

Actions proposed for specific sites were:

- Review Base records documenting clean-up and disposal of PCB contaminated soils in the PCB spill areas.
- Collect six shallow hand soil samples, two from each of the three PCB spill areas, and combine the samples from each area into three composites.

- Drill two exploratory borings in the trichloroethylene spill area in DA-4 adjacent to the liquid oxygen plant to analyze subsurface soils for volatile organic compounds (VOA's). The borings were to be keyed to areas of surface vegetation distress. The samples were to be collected continuously to the top of the hardpan or 10 feet, whichever occurred first.

In addition to these specific actions, WESTON proposed to install a total of seven monitor wells and five lysimeters in the West Flightline Sector. Four monitor wells were to be installed at the WLFZ. The WLFZ encompasses LF-4, DP-5, DP-6, and FT-2. By locating three monitor wells downgradient from these sites and one upgradient, WESTON proposed to assess the potential migration of contamination from sites within the landfill zone through the shallow groundwater aquifer.

In the area of fuel spills 1 through 4, one monitor well and four lysimeters were proposed. The monitor well was to be located downgradient of FS-3, and one lysimeter downgradient of each fuel spill site, to determine any potential soil or groundwater contamination from the fuel spill sites.

One monitor well was proposed at DA-2, and one monitor well and one lysimeter (paired) downgradient from FT-3. All monitor wells were expected to average 100 feet in depth and lysimeters 10 feet in depth. The proposed completion, surveying, and sampling procedure for these wells and lysimeters were accomplished following the general considerations discussed in Subsection 3.1.1.

### 3.1.3 Results

The results of the field program were carefully analyzed as they were generated and incorporated into the remaining field investigations. Preliminary findings and data analysis efforts were presented in short interim reports, and a full evaluation is documented in this report, for the purpose of confirming the presence or absence of an environmental contamination problem at each of the investigated sites. These results have also been used to develop recommendations for further investigation in the Phase II effort. These recommendations, summarized in Section 6 of this report, are specifically tailored to support concept engineering evaluation of remedial action alternatives for each of the sites.



### 3.2 REVIEW OF AERIAL PHOTOGRAPHS AND BASE DOCUMENTS

#### 3.2.1 General

Prior to and during the field investigation, WESTON assembled and reviewed aerial photographs of CAFB available from 1942, 1950, 1957, 1961, 1968, 1970, 1972, 1980, and 1983. Sources for these photographs included Base files, the Merced County Tax Assessor's Office, and the USDA/ASCS office in Salt Lake City, Utah. USGS topographic quadrangle sheets (dated 1961, photorevised in 1976) were used to supplement existing aerial photography. In addition, historic plans available in the Civil Engineering Drafting Office were reviewed. These included a set of topographic maps of the CAFB area made by the Corps of Engineers between 1948 and 1952, with updates until the early 1960's, design plans for Building 1550 (the FITS Alert Hanger), and early blueprints for Building T-52. WESTON worked with the Base Bioenvironmental Engineering Office (BEE) to obtain additional documents and verbal information concerning specific buildings and sites of potential concern in the IRP investigation. Additional information and early ground level photographs were reviewed in the Base Historian's Office. Most of the information obtained from this review of aerial photographs and historic Base documents has been incorporated into the discussion of Base history and Phase II investigation sites (Subsection 1.4). A preliminary review was used to determine the areal extent of the investigation sites and to finalize monitor well drilling sites. In addition, a detailed review of photographs and plans was used to design the extent, orientation, and spacing of grids for the geophysical surveys of sites DA-8, DP-3, and LF-5, as described in Subsection 3.3.2.

#### 3.2.2 PCB Spill Area

Records from the Base BEE Office documenting the clean-up of the PCB spill area in the West Flightline Sector were reviewed. They indicated that spills of contaminated oil from a broken transformer and a leaking drum had occurred in late 1982 - early 1983.

Three phases of excavation and removal of PCB contaminated soil had been accomplished by subcontractors to the Base CE Office in August 1983, September 1983, and February to April 1984. In May 1983, oil from the leaking drum had been analyzed and was found to have a concentration of 510,000 ppm of PCB; nearby soils had concentrations of PCB ranging from 4 to 7,600 ppm. In September 1984, after the third phase of clean-up, the Base BEE Office sampled soils from the excavation and found concentrations of PCB in soils ranging from 25 to 17,000 ppm. On 12 April 1985, subcontractors to the Base performed auger borings at the site and collected new soil samples for the purpose of developing a vertical profile of PCB concentrations and planning further clean up efforts. The results of this investigation were not available to WESTON by the end of the Phase II, Stage 1 field effort. Because sampling and clean-up efforts were still ongoing at the time, WESTON did not collect any samples from this site.

### 3.3 FIELD INVESTIGATION

Based on the program described in Subsection 3.1, a field investigation was conducted at CAFB to define the hydrologic and geologic setting of the Base, and to determine the possible presence of hazardous environmental contaminants that may have resulted from past product storage and handling or waste disposal practices at the Base.

The elements of the field investigation included:

- Drilling and installation of 27 monitor wells in the shallow aquifer in locations associated with 10 of the 16 investigation sites in all five sectors.
- Drilling and installation of 11 lysimeters above hardpan to test for the presence of perched groundwater in the shallow subsurface at five sites distributed among the five sectors.
- Drilling and sampling of six soil borings at two sites.
- Sampling of drainage ditch sediments at three sites.
- Sampling of surface soils at a single site.
- Surface geophysical (GPR and magnetometer) surveys at three sites.
- Staff gage installation at 10 drainage ditch locations associated with two sites in the Main Base and South Sectors.
- Two rounds of water sampling and water level elevation surveys at over 65 surface and groundwater sampling stations in all five sectors.
- Pilot-test operations performed on PW-3 to test the hypothesis of down-casing leakage between the shallow and confined aquifers in the area of the Main Base production wells.

The subsections below review the schedule of activities followed in performing the field investigation, and a detail of activities on a sector-by-sector basis, followed by details on the specific elements of the field investigation.

### 3.3.1 Schedule of Activities

The field investigation at CAFB began on 22 October 1984 and was completed on 12 April 1985. Table 3-4 is a schedule of WESTON's field activities at CAFB.

### 3.3.2 Site-Specific Details

This subsection reviews the field investigation on a sector-by-sector basis, highlighting those areas where field conditions or other considerations dictated alterations in the planned activities as outlined in Subsection 3.1.2. In general, activities were performed as planned except for the following instances:

- Although 11 lysimeters were installed as required, hardpan was not always encountered at the sites specified in the Task Order. In such cases, a new location was chosen, and a lysimeter installed at that new location if hardpan was encountered. As a result, one lysimeter was moved from a downgradient to an up-gradient location at the SLFZ (both in the South Sector), and one lysimeter was moved from the NLFZ (North Sector) to a location downgradient from DA-8 in the Main Base Sector.
- A total of 10 staff gages were installed instead of the nine required by the Task Order, because excess materials were available; the tenth staff gage was used for water level measurements only, and not as a surface water sampling station.
- Samples of shallow soils were not collected from the PCB spill area because of ongoing cleanup activities during the period of the Phase II, Stage I field investigation.
- The water sampling program included only those Base production wells that had operable pumps at the time of sampling.
- Attempts to sample the lysimeters were unsuccessful because the lysimeters were dry in both sampling rounds.
- Pilot-test operations at PW-3 were modified on the basis of results from initial well-logging activities (Subsection 3.3.6). The long-term pumping test period was altered so that samples could be collected at a greater frequency early in the test period.

Table 3-4

Schedule of Field Activities

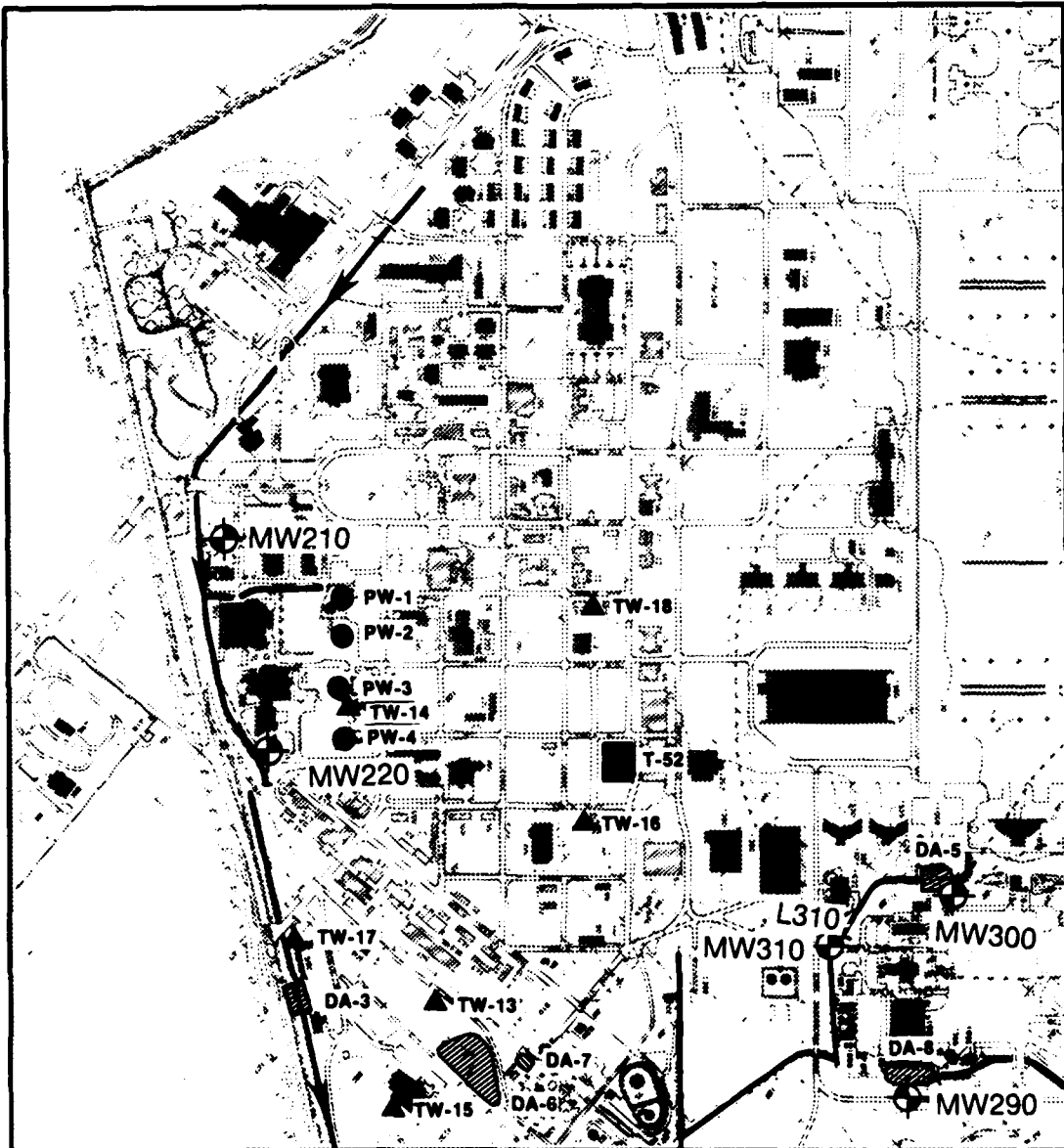
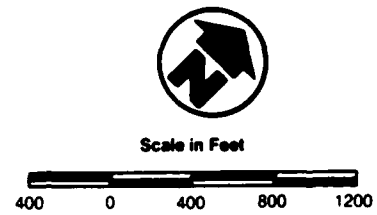
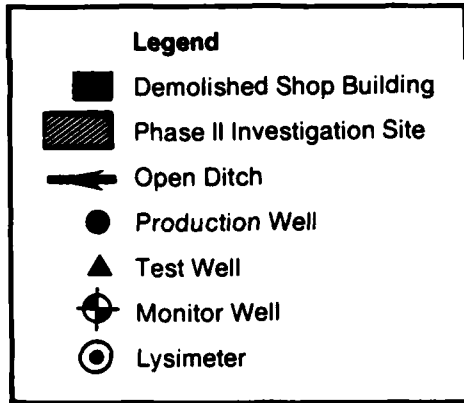
Date	Activity
10-11 October 1984	Preperformance meeting at CAFB
22 October - 4 December 1984	Drilling and construction of 27 monitor wells
30 October 1984 - 21 January 1985	Monitor well development and drilling site restoration
31 October 1984	Collection of soil samples at DA-7
9-10 November 1984	Ditch sediment sampling at three sites
12 November 1984 - 16 January 1985	Pilot test operations on PW-3
14-17 November 1984	Drilling and construction of 11 lysimeters
17-18 November 1984	Drilling and sampling of six soil borings
28 November - 12 December 1984	GPR/magnetometer surveys at three sites
14-20 December 1984	Well and staff gage elevation survey
17 January - 22 February 1985	Long-term pumping test on PW-3
22 January - 1 February 1985	Groundwater sampling, round 1
4 March 1985	New production well and surface water sampling, round 1
1-12 April 1985	Surface and groundwater sampling, round 2

Field locations and basic data for wells and lysimeters are given in this subsection on a sector-by-sector basis. Additional general information on drilling methods, materials, and equipment is given in Subsection 3.3.3.

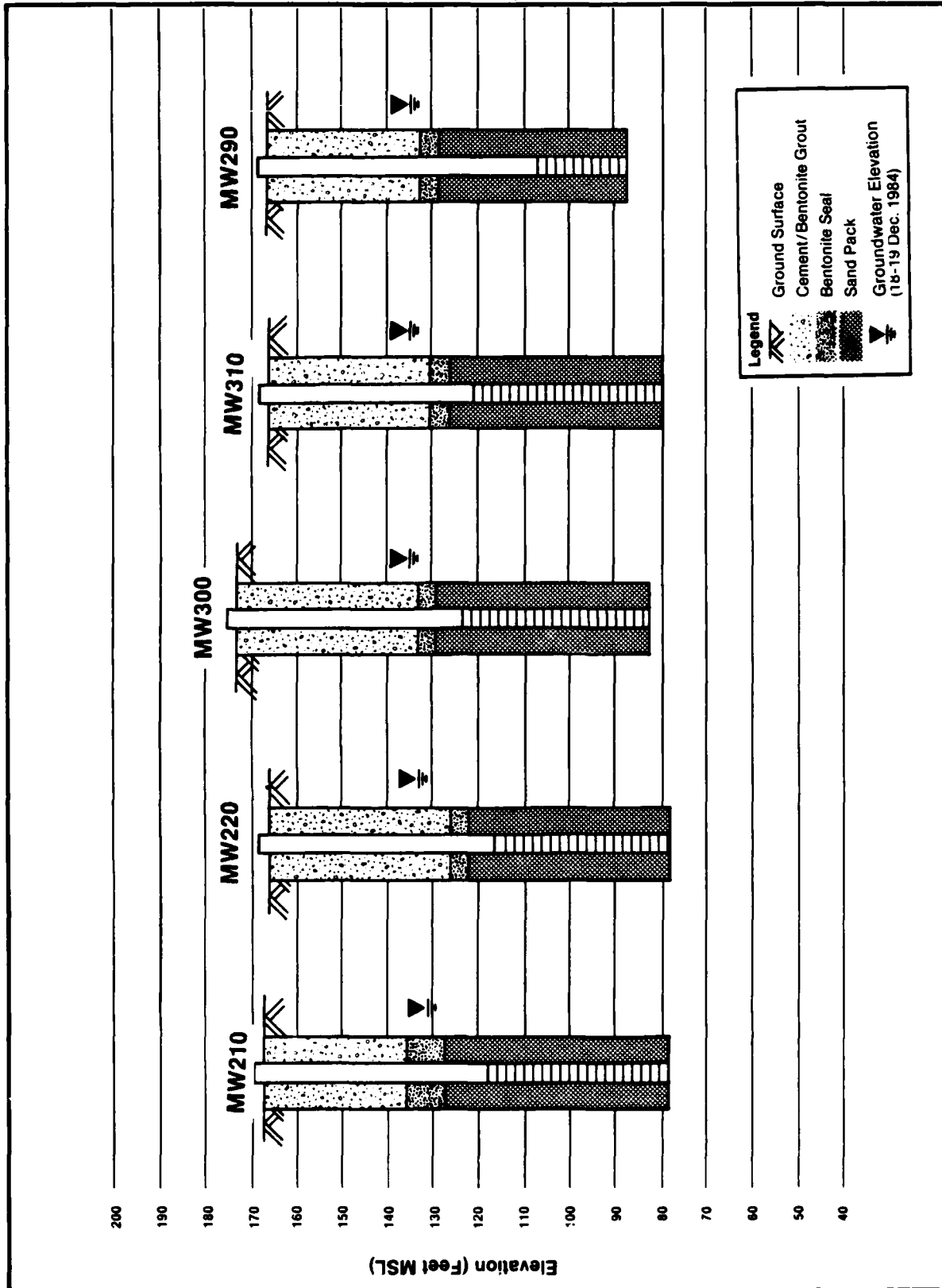
#### 3.3.2.1 Main Base Sector

Investigation sites in the Main Base Sector included five discharge areas and the TCE plume (Figure 1-3). A total of five monitor wells were installed in the Main Base Sector, as shown in Figure 3-1. MW-210 and MW-220 were installed along the Base boundary in the presumed downgradient direction from the TCE plume area. Three wells were installed in Discharge Area 8, MW-290 in the presumed upgradient direction from the site, and MW-300 and MW-310 in the presumed downgradient direction. The five wells were drilled to an average depth of 110 feet and averaged 90 feet in finished depth. One well (MW-300) had to be moved and redrilled when water-saturated gravels were encountered that were so permeable that mud circulation could not be maintained. All wells were completed with 40 feet of screen except MW-290. The shallow sediments encountered in MW-290 had a high percentage of clay and only a relatively thin water-bearing sand zone; therefore, a screen length of only 20 feet was selected for that well. A monitor well completion summary for all five wells in the Main Base Sector is provided in Figure 3-2.

One lysimeter (L-310) was installed downgradient from Discharge Area 8, adjacent to MW-310. This lysimeter, although not required by the Task Order, was installed to verify the presence or absence of perched water on hardpan in this location. Earlier monitor well drilling and ditch sediment sampling efforts revealed that this area of the Base is underlain by significant hardpan in the shallow subsurface, and it was thought likely that lateral seepage from the drainage ditch might be occurring and could be monitored in a shallow saturated zone above hardpan. The lysimeter was installed to a total depth of about 11 feet, including 5 feet of screen. Although approximately 1.5 feet of water was found in the bottom of L-310 on 19 December 1984, the water level subsequently fell and the lysimeter, along



**FIGURE 3-1 MONITOR WELL AND LYSIMETER LOCATIONS, MAIN BASE SECTOR**



**FIGURE 3-2 WELL CONSTRUCTION SUMMARY, MAIN BASE SECTOR**

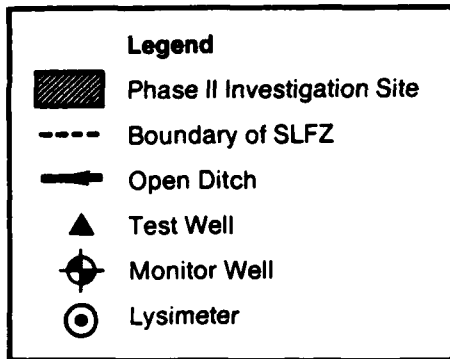
with all the others, was found to be dry during both water sampling periods in January and April 1985. The tenth staff gage (SG-10), was installed in the ditch next to L-310, for the purposes of water level comparison between the ditch and perched water in the lysimeter. Between 19 December 1984 and 21 January 1985 the water level elevation at SG-10 averaged 163.5 feet MSL. Between these same dates the water level elevation in L-310 fell from 157.0 to 156.4 feet MSL, and by 1 February 1985 L-310 was dry; it remained dry throughout the wet season. During the same period, the water level in MW-310, the adjacent monitor well, rose from 134.5 to 134.7 feet MSL. It is thought that the water found initially in L-310 was water introduced at the time of lysimeter construction and completion, and did not represent true perched groundwater.

Additional field activities in the Main Base Sector included the collection of ditch sediment samples from three sites (DA-8, DA-5, and DA-3), as described in Subsection 3.3.3.4; the collection of soil samples by hand at one site (DA-7), as described in Subsection 3.3.3.5; a GPR/magnetometer survey to detect an overflow pipe at one site (DA-8), as described in Subsection 3.3.4; installation of three staff gages adjacent to and downstream from DA-8; water sampling and water level elevation measurements as described in Subsection 3.3.5; and pilot test operations on PW-3, as described in Subsection 3.3.6.

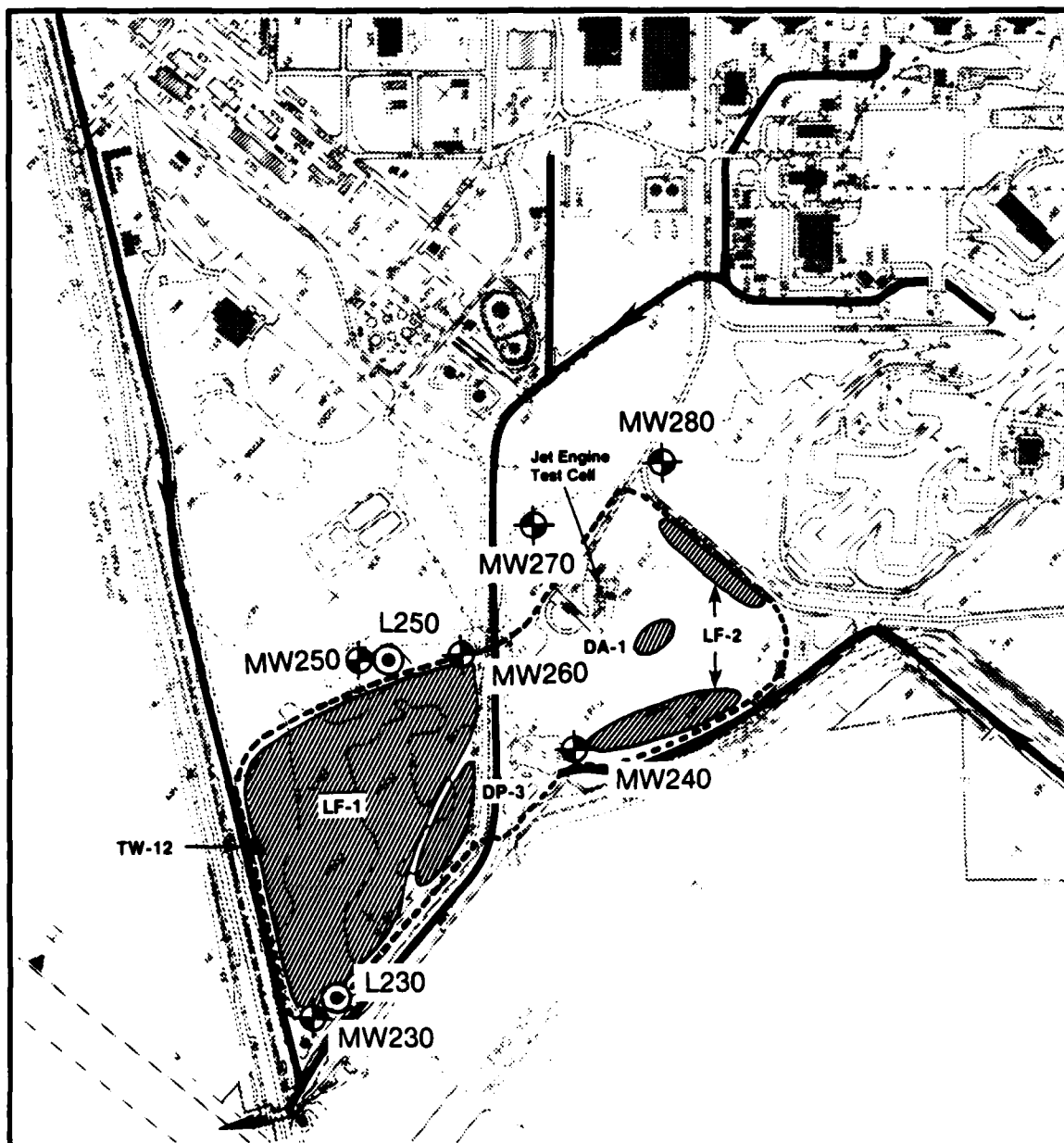
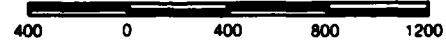
#### 3.3.2.2 South Sector

Investigation sites in the South Sector consisted of the SLFZ, which includes two landfills (LF-1 and LF-2), one discharge area (DA-1), and four disposal pits (DP-1 through DP-4).

A total of six monitor wells and two lysimeters were installed in the South Sector, at locations shown in Figure 3-3. MW-230 and MW-240 were installed in the presumed upgradient directions from LF-1 and LF-2, respectively; MW-250, MW-260, MW-270, and MW-280 were installed in presumed downgradient directions from the two landfills. One lysimeter (L-250) was paired with MW-250, downgradient from LF-1. No hardpan was encountered in drilling adjacent to MW-260, and therefore the second lysimeter (L-230) was installed next to MW-230 near the confluence of the two perimeter drainage ditches at the southern Base boundary.



Scale in Feet



**FIGURE 3-3 MONITOR WELL AND LYSIMETER LOCATIONS, SOUTH SECTOR**

The six monitor wells were drilled to an average depth of 105 feet, and had an average finished depth of 92 feet. A summary of monitor well construction is given in Figure 3-4. The lysimeters L-230 and L-250 were installed to total depths of about 5 and 10 feet, respectively, and included 2 and 5 feet of screen each. Both were installed on top of hardpan, and remained dry throughout the period of investigation.

Four soil borings were drilled in the South Sector, at locations directly downstream from the jet engine test cell, in runoff drainage pathways, and in the area of runoff ponding. Soil boring locations are shown in Figure 3-5. The borings were drilled and sampled to a total depth of 10 feet, as described in Subsection 3.3.3.3.

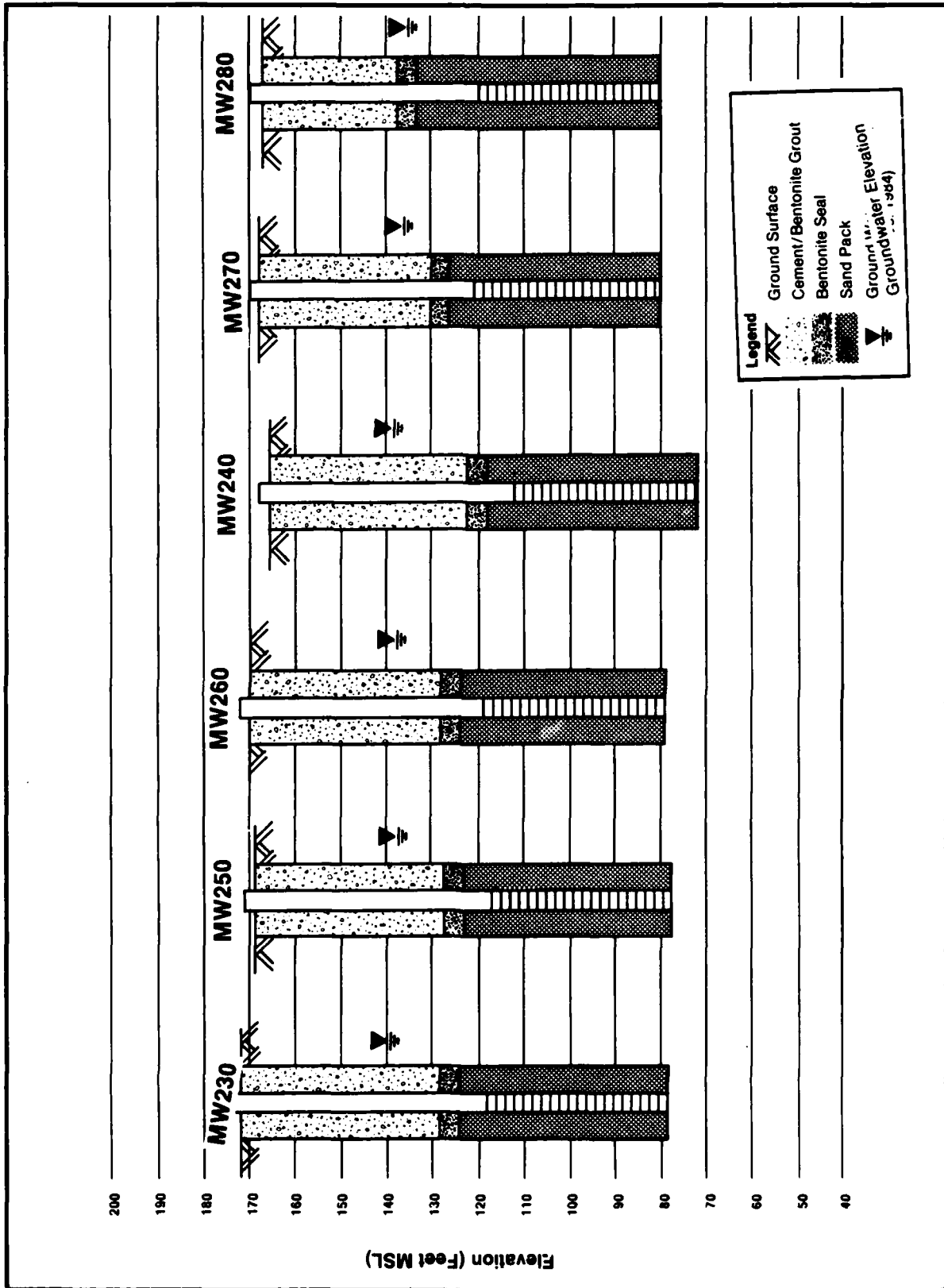
Additional field activities in the South Sector included a GPR/magnetometer survey of the ground surface above the approximate location of DP-3, as described in Subsection 3.3.4; installation of six staff gages upstream and adjacent to the SLFZ; and water level measurement and water sampling as described in Subsection 3.3.5.

#### 3.3.2.3 East Sector

Investigation sites in the East Sector included Fire-Training Area 1 (FT-1) and Landfill 3 (LF-3). A total of five monitor wells were installed in this sector at locations shown in Figure 3-6. MW-320 was installed in the presumed upgradient direction from FT-1; MW-330 and MW-340 in presumed downgradient directions. MW-460 and MW-470 were installed in presumed downgradient directions from LF-3. Two lysimeters (L-330 and L-340) were installed at locations paired with the downgradient wells for FT-1.

The monitor wells were drilled to an average depth of 108 feet, and encountered interlayered clays, silts, and sands. An attempt was made to screen the predominant sand zone encountered below a level of 40 feet. All wells were constructed with 40 feet of screen except MW-320, which was constructed with a 30-foot screen. Finished well depths averaged 80 feet around FT-1, 97 feet downgradient of LF-3. Well construction summaries are shown in Figure 3-7. The two lysimeters, L-330 and L-340, were finished at depths of about 9 and 5 feet, respectively, and included 5 and 2 feet of screen.

Other field activities in the East Sector included water level measurements and water sampling as described in Subsection 3.3.5 below.








**FIGURE 3-4 WELL CONSTRUCTION SUMMARY, SOUTH SECTOR**

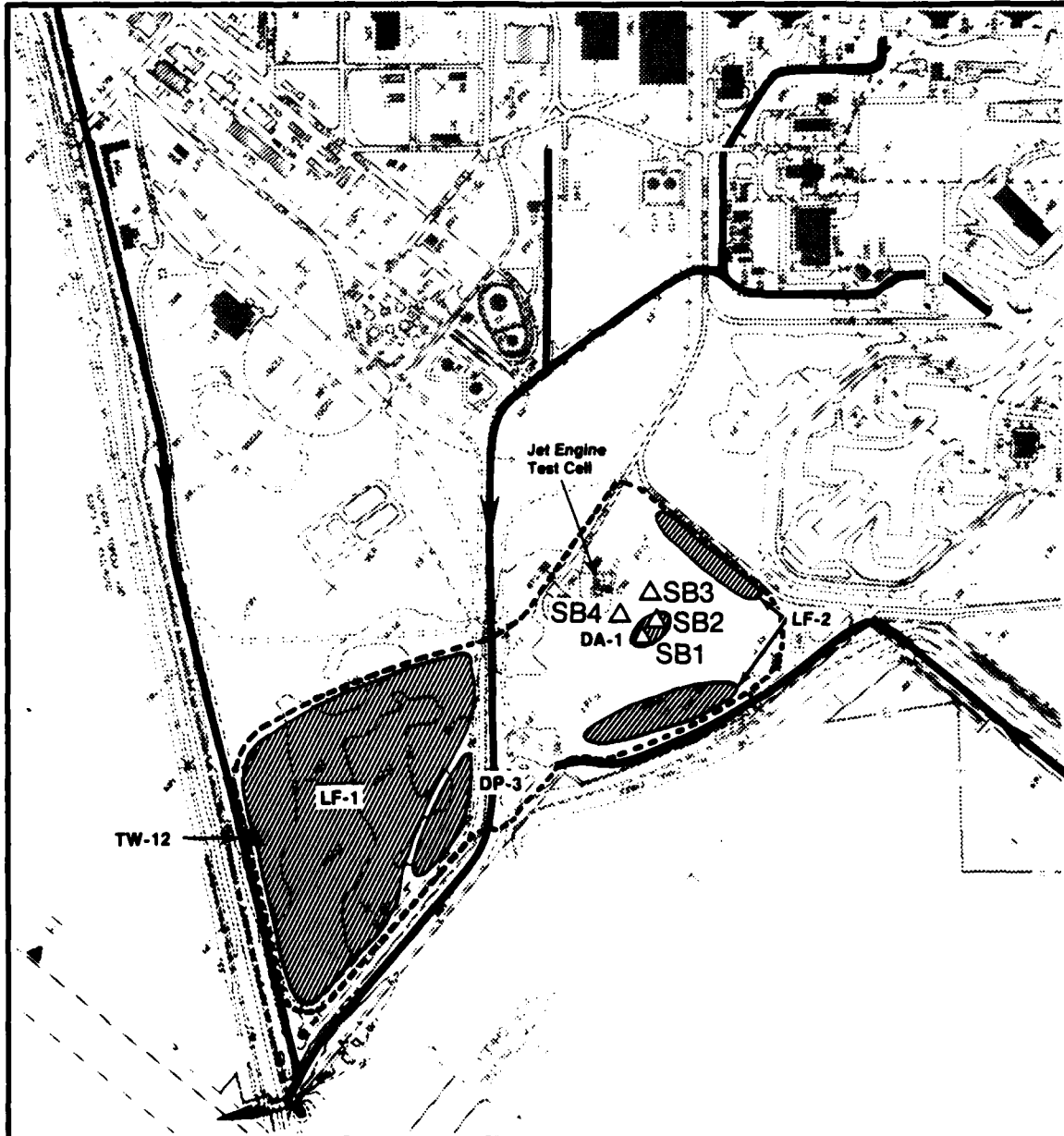


Scale in Feet

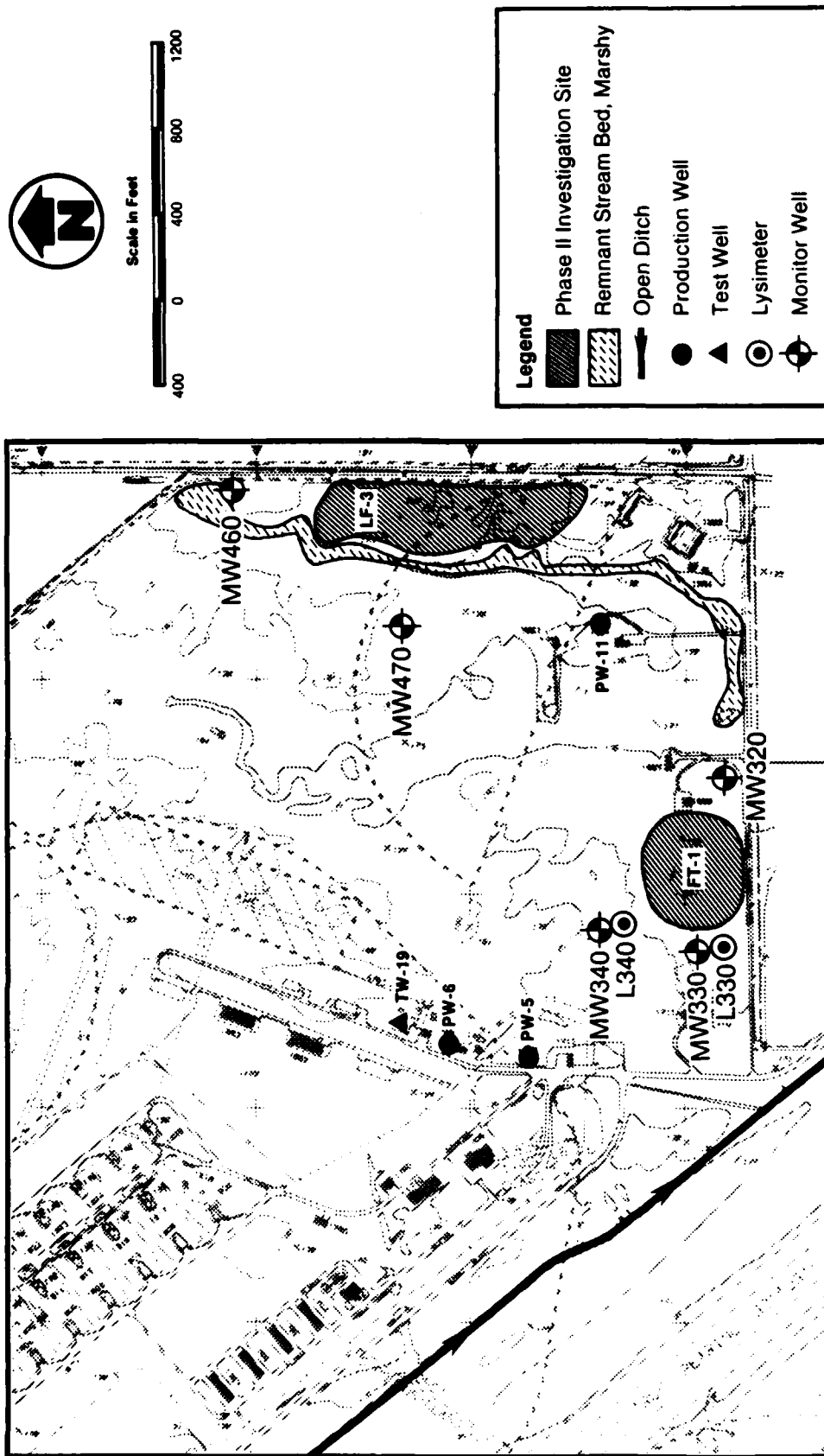
400 0 400 800 1200

**Legend**

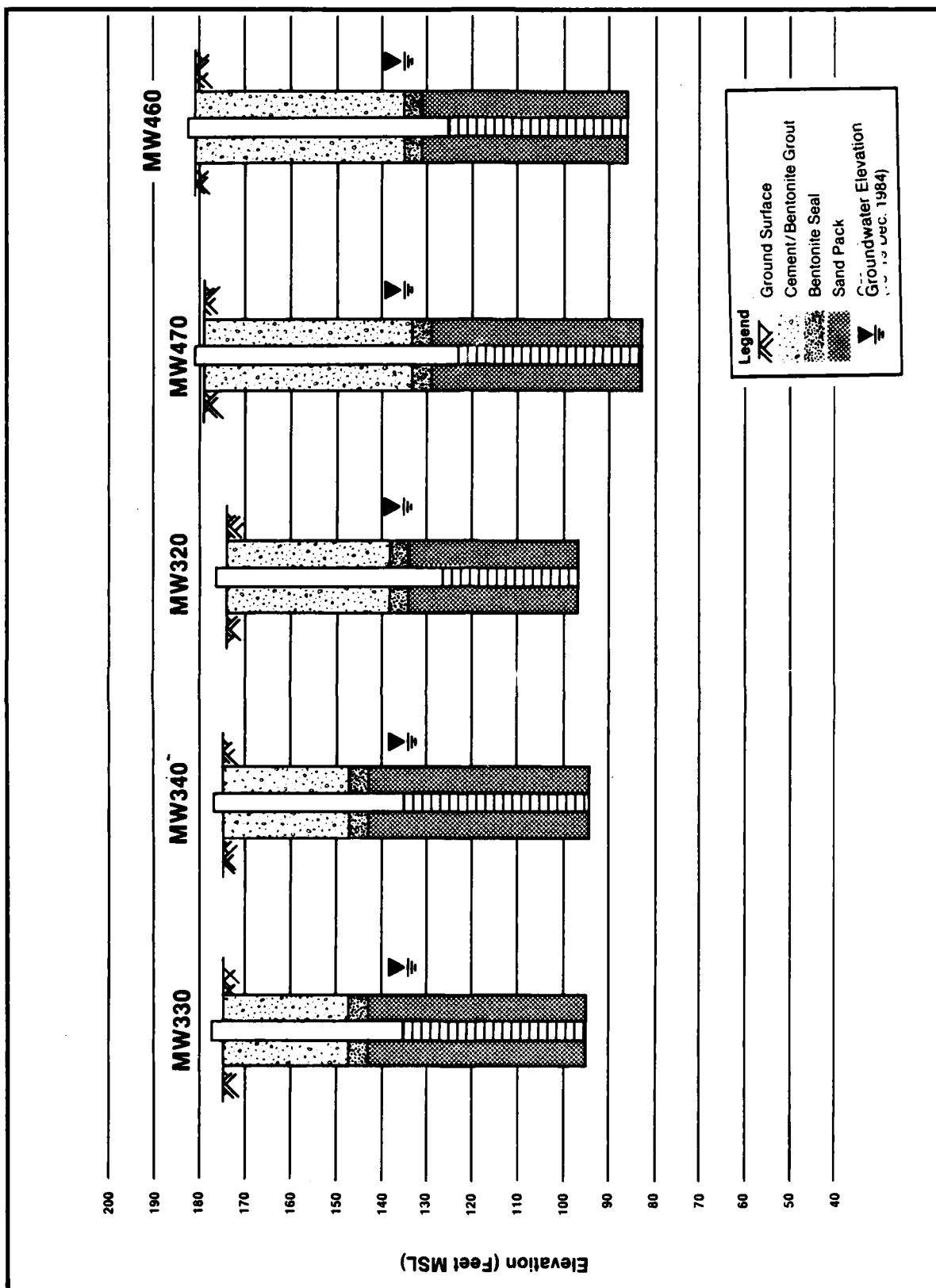
-  Phase II Investigation Site
-  Boundary of SLFZ
-  Open Ditch
-  Test Well
-  Soil Boring Locations



**FIGURE 3-5 IL BORING LOCATIONS , SOUTH SECTOR**



**FIGURE 3-6 MONITOR WELL AND LYSIMETER LOCATIONS, EAST SECTOR**



**FIGURE 3-7 WELL CONSTRUCTION SUMMARY, EAST SECTOR**

#### 3.3.2.4 North Sector

Investigation sites in the North Sector consisted of the NLFZ, which includes one landfill (LF-5) and three disposal pits.

Four monitor wells were installed in this sector, in locations shown in Figure 3-8. MW-350 was drilled in the presumed upgradient direction from the NLFZ; MW-360, MW-370, and MW-380 were drilled along the Base boundary in the presumed downgradient direction. One lysimeter, L-380, was paired with MW-380. An attempt was made to install a second lysimeter, paired with L-360, but no hardpan was encountered.

The monitor wells were drilled to an average depth of 110 feet, and constructed with 40 feet of screen each. Finished depths averaged 92 feet. Well construction summaries are shown in Figure 3-9. The boundary wells (MW-360, MW-370, and MW-380) were drilled through 15 to 30 feet of shallow clay and inter-layered clay and sand into coarse sand between 60 and 90 feet; the sand was characteristic of other shallow aquifer materials encountered, variegated in color, with a predominant quartz content. MW-350, however, was drilled in a significantly different geologic environment. It encountered a medium to coarse white sand, calcareous in appearance, all the way from 13 to 113 feet below ground surface, and underlain by reddish-brown fine sandy clay. This area apparently represents a distinct channel, cut through the predominant geologic materials that are described in Section 4, and filled at a later date. Materials comparable to those encountered in MW-350 were not encountered in any other borings drilled at CAFB for this investigation.

Lysimeter L-380 was finished at approximately 6 feet below ground surface, with 3 feet of screen.

Other field activities in the North Sector included a GPR/magnetometer survey of the eastern half of LF-5 (see Subsection 3.3.4), and water level measurements and sampling (see Subsection 3.3.5).

#### 3.3.2.5 West Flightline Sector

The investigation sites in the West Flightline Sector include the WLFZ (LF-4, FT-2, and two disposal pits), the area of PCB spills 1 to 3 (addressed in Subsection 3.2.2), the area of fuel spills 1 to 4 (FS1-4) on the flightline, two discharge areas (DA-2 and DA-4), and Fire-Training Area 3 (FT-3).

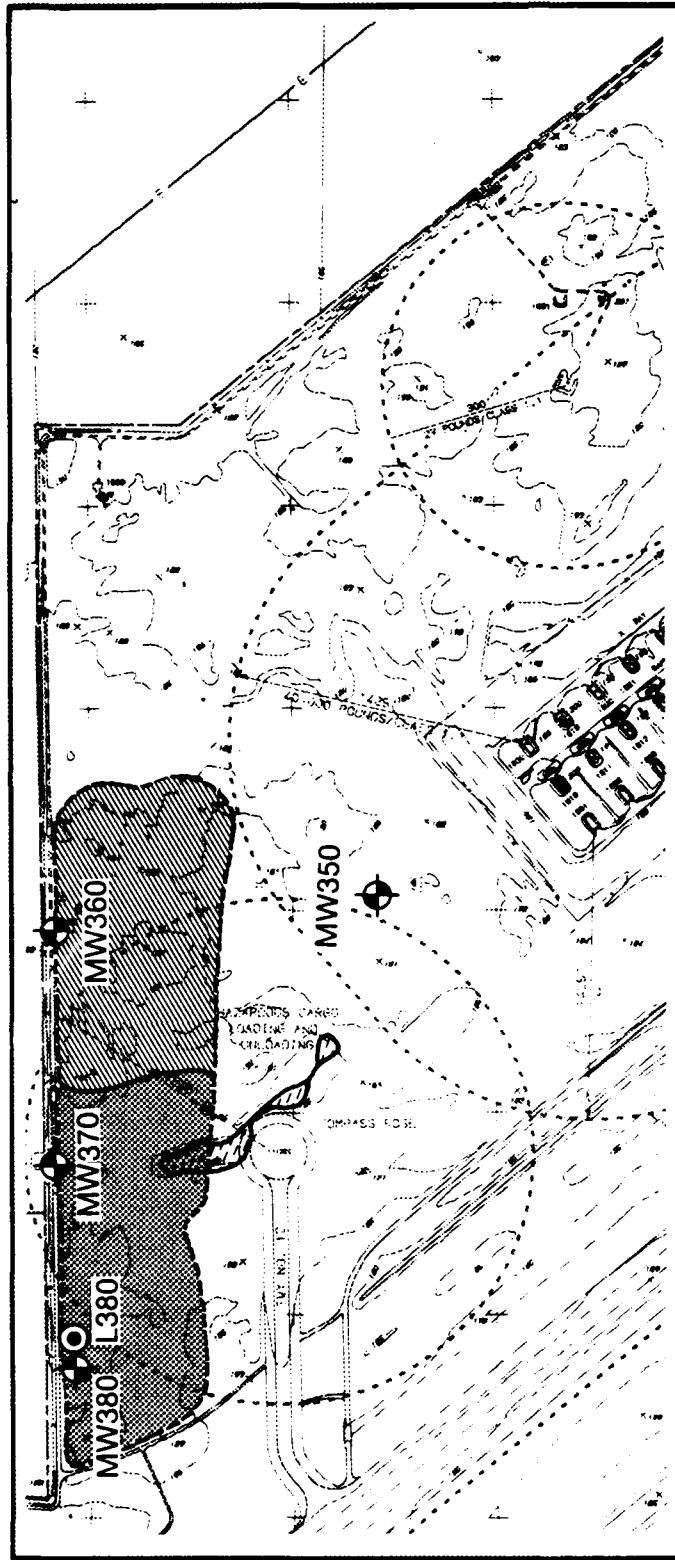
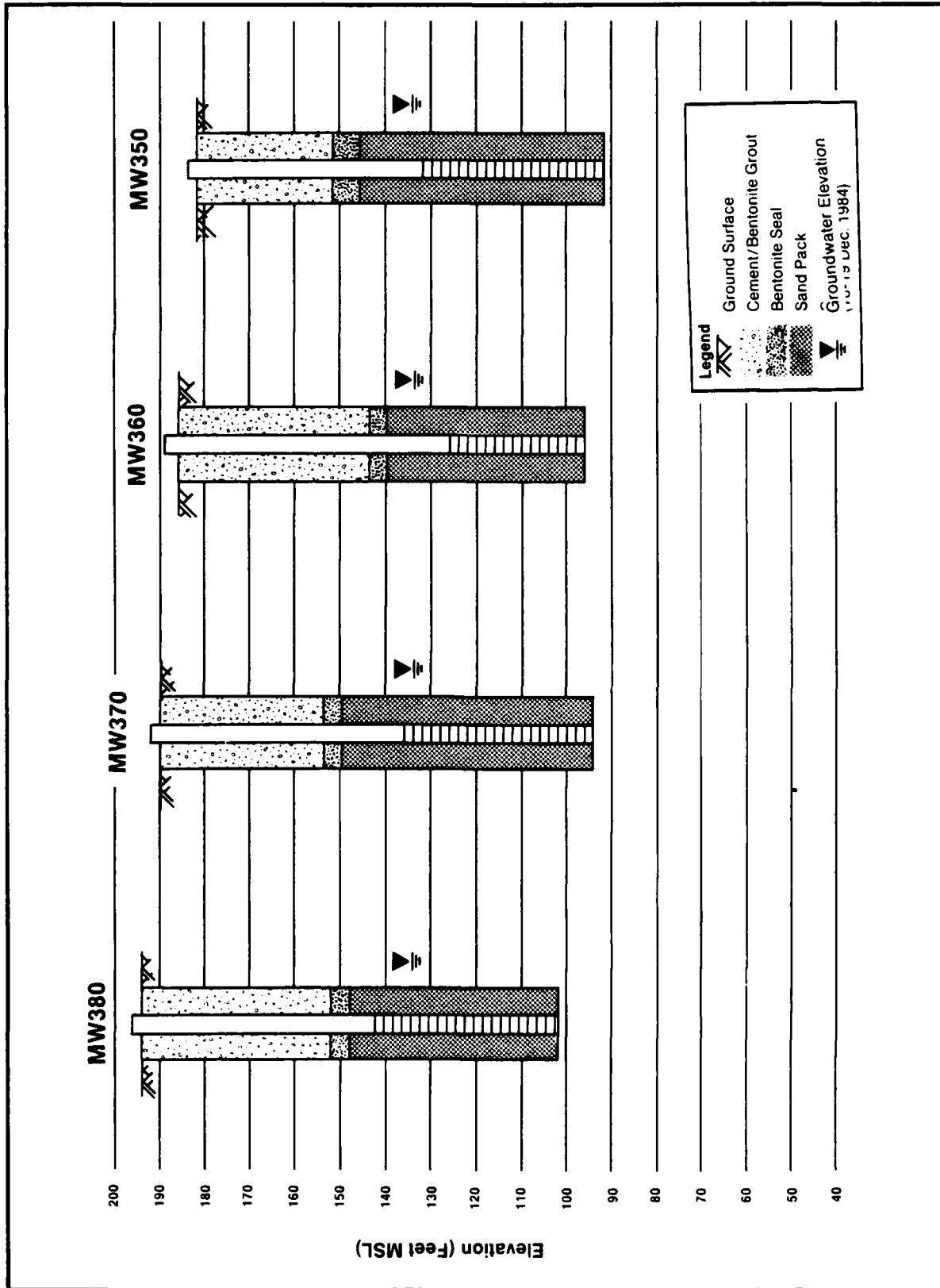


FIGURE 3-8 MONITOR WELL AND LYSIMETER LOCATIONS, NORTH SECTOR



**FIGURE 3-9 WELL CONSTRUCTION SUMMARY, NORTH SECTOR**

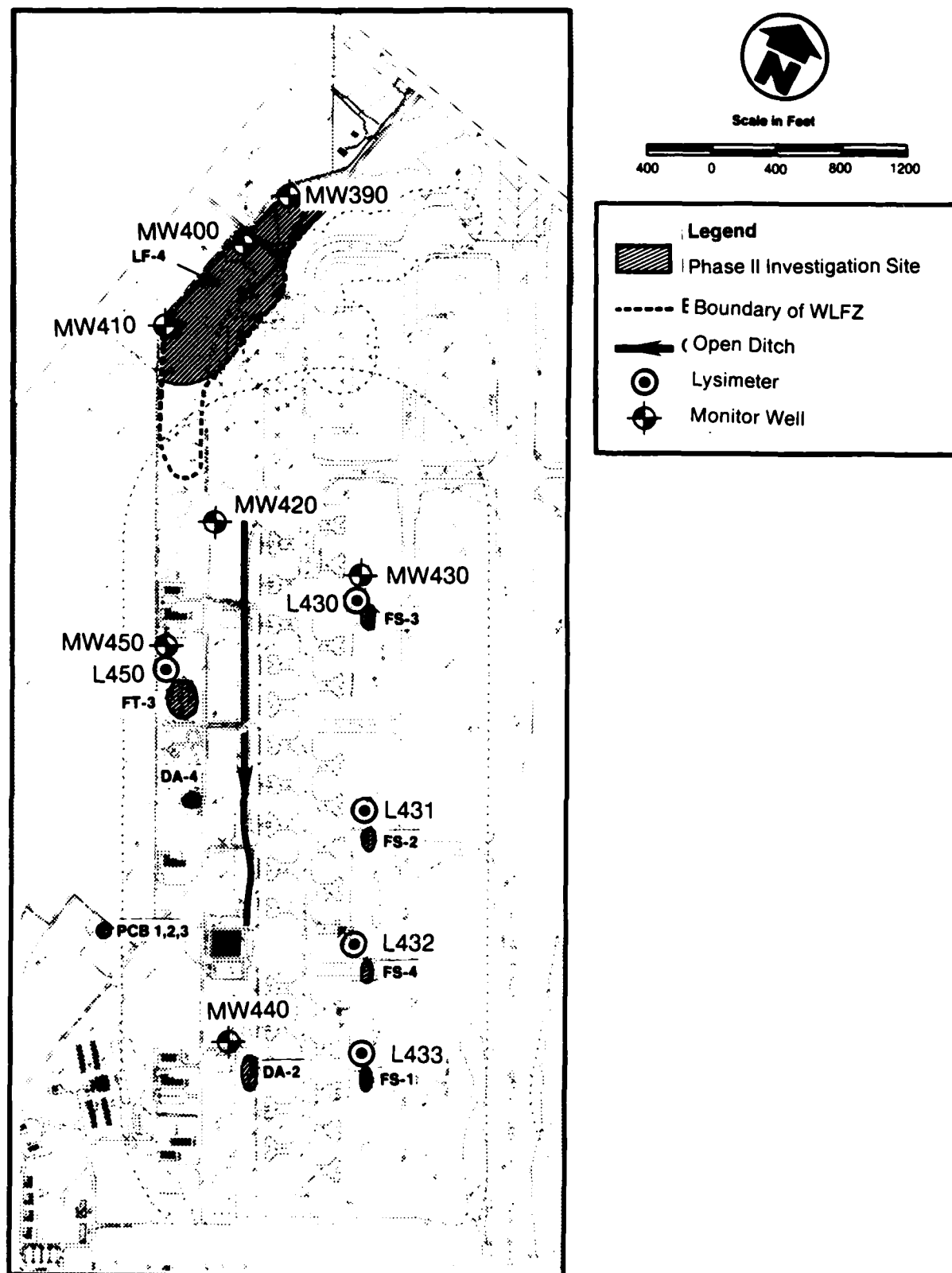
Seven monitor wells and five lysimeters were installed in the West Flightline Sector, at locations shown in Figure 3-10. Monitor wells MW-390, MW-400, and MW-410 were drilled along the Base boundary in the presumed downgradient location from the WLFZ. MW-420 was drilled in the presumed upgradient direction. MW-430 was drilled in the presumed downgradient location from FS-1 through FS-4, MW-440 in the presumed downgradient direction from DA-2, and MW-450 in the presumed downgradient direction from FT-3. One lysimeter was paired with MW-450, and one with MW-430. The other three lysimeters were located in the presumed downgradient direction from the other three fuel spill locations not covered by MW-430/L-430.

The seven monitor wells were drilled to an approximate average depth of 112 feet, and were finished at an average depth of about 96 feet, except MW-430, which was finished at 78 feet. Five wells were constructed with 40 feet of screen; the other two (MW-390 and MW-440) with 20 feet of screen. Screen length was based on the thickness of aquifer materials (sands or gravels) encountered. Summaries of monitor well construction are shown in Figure 3-11.

The five lysimeters were finished at depths ranging from 5 to over 10 feet, depending on the depth to hardpan, and included from 2 to 5 feet of screen (details of lysimeter construction are listed in Table 3-6).

Two soil borings were drilled just west of the perimeter fence of the Liquid Oxygen Plant, at DA-4. Locations are shown in Figure 3-12. The holes were drilled to a total depth of 10 feet and sampled as described in Subsection 3.3.3.3.

Other field activities in the West Flightline Sector included water level measurements and water sampling as described in Subsection 3.3.5.



**FIGURE 3-10 MONITOR WELL AND LYSIMETER LOCATIONS, WEST FLIGHTLINE SECTOR**

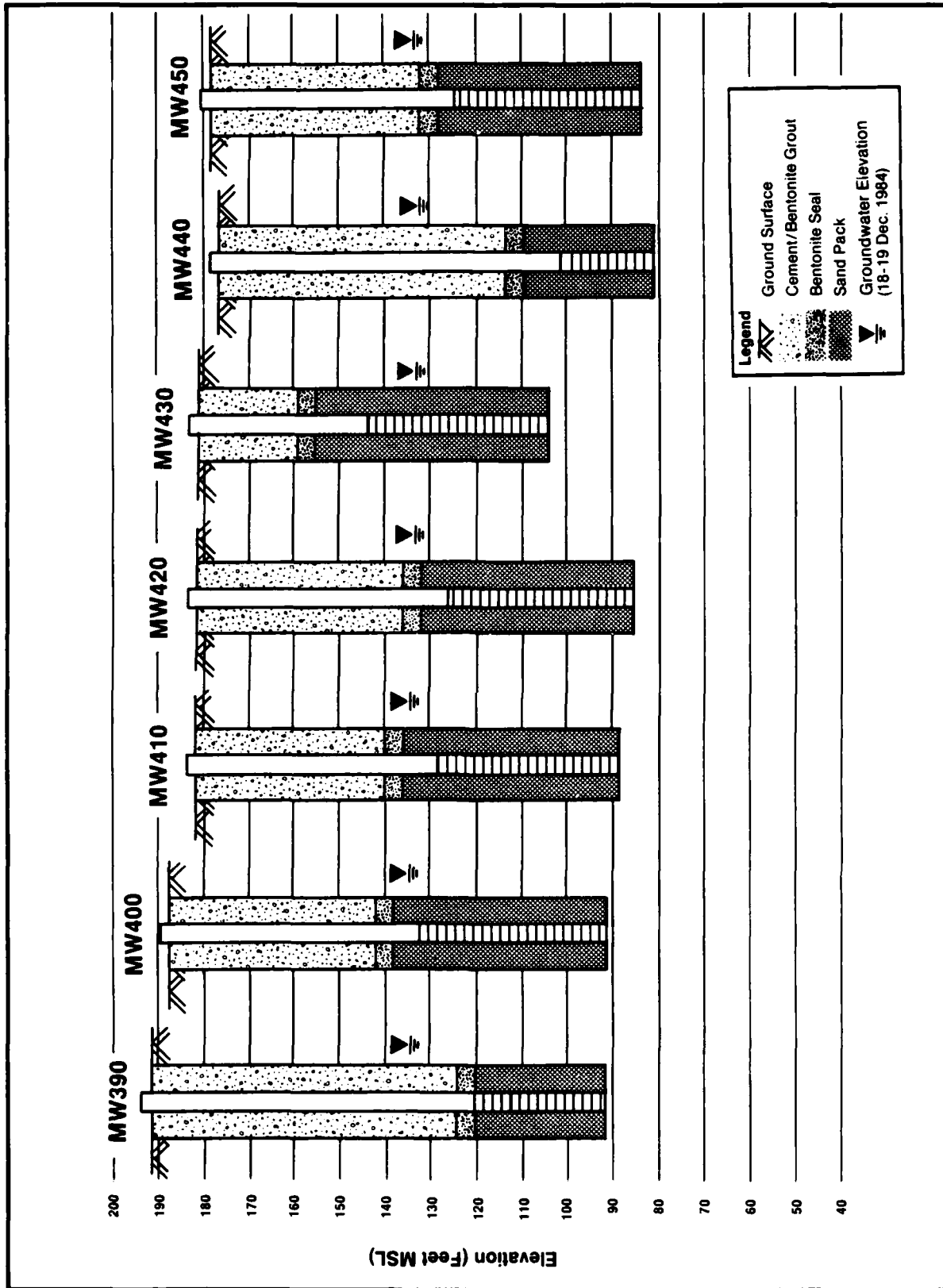
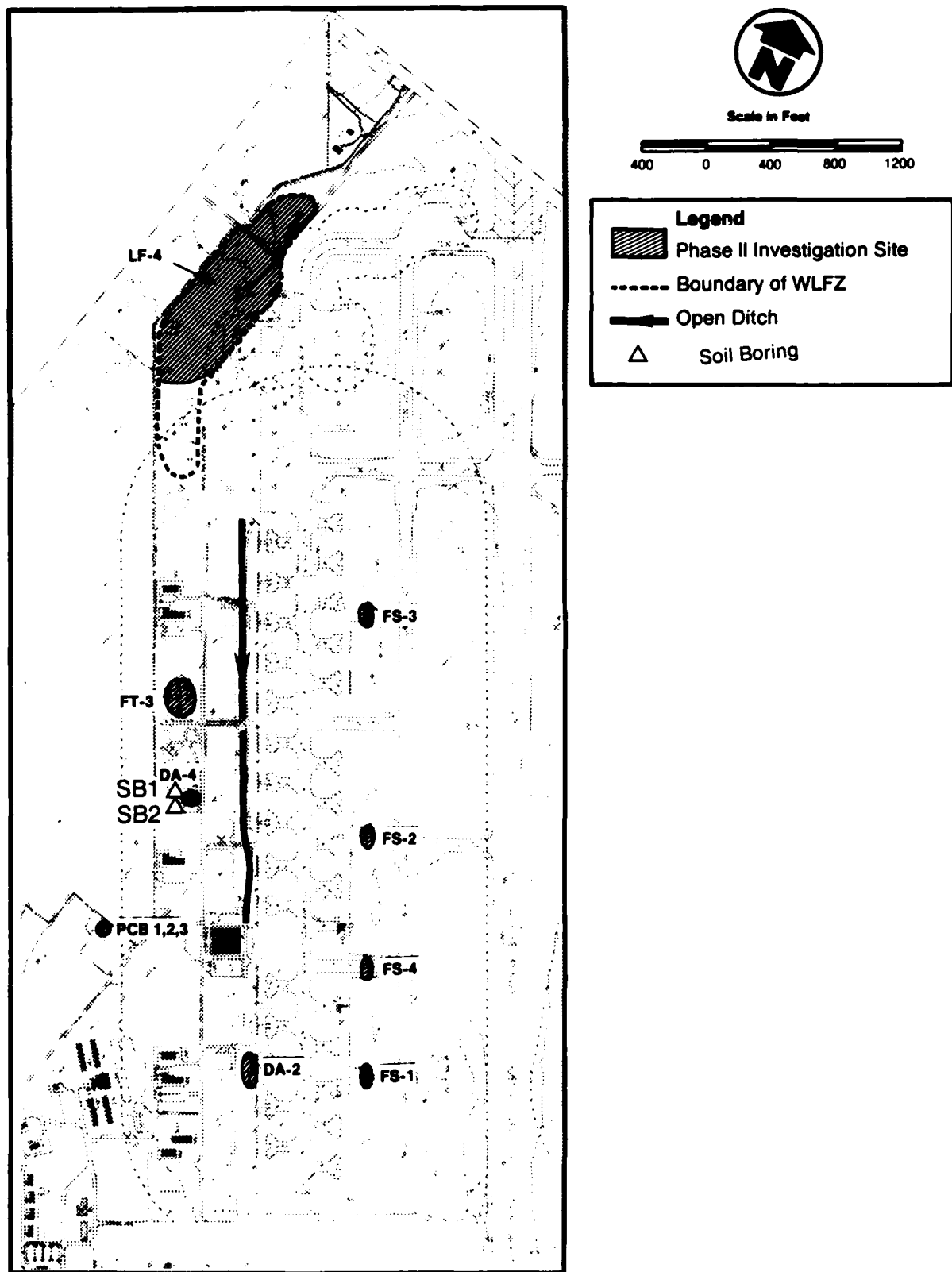


FIGURE 3-11 WELL CONSTRUCTION SUMMARY, WEST FLIGHTLINE SECTOR



**FIGURE 3-12 SOIL BORING LOCATIONS, WEST FLIGHTLINE SECTOR**

### 3.3.3 Drilling and Sediment Sampling Program

A total of 27 monitor wells and 11 lysimeters were installed at CAFB in the Phase II, Stage 1 investigation. The completed depth of the monitor wells averaged 95 feet, and the depth of the lysimeters averaged 10 feet. Six soil borings were also drilled during the field program to a depth of 10 feet each. Ditch sediment samples were collected from eight locations by coring with a split-spoon sampler driven from a development rig. The drilling was performed by crews from Stang Drilling and Exploration, Inc. of Rancho Cordova, California, under the direct supervision of on-site WESTON geologists and soil scientists. The monitor wells were installed using either a Mayhew 1000 or a Simco 1000 mud rotary drill rig mounted on a Ford two-ton Statebody truck. The lysimeters and soil borings were drilled with a mobile drill B-53 hollow-stem auger boring rig.

#### 3.3.3.1 Monitor Well Drilling and Construction

All monitor wells were drilled by mud rotary methods, using 1,000 to 1,500 gallons of fluid each, mixed from 150 to 300 pounds of bentonite powder, and finished water from the Main Base supply. Due to the use of drilling mud, the degree of saturation of the sedimentary materials penetrated could not be determined during drilling. In general, the sediments encountered consisted of interlayered sands, silty sands, and clays underlain by well-sorted, rounded medium to coarse sand or fine to coarse stream gravel. In 23 of the 27 monitor wells, relatively coarse aquifer materials were found to be overlain by one or several shallow clay layers with occasional sand interlayers, and occurring at depths between 20 and 80 feet. Total finished well depths were chosen on the basis of lithology, as well as regional groundwater level information available in the Phase I report. Perched groundwater may occur locally above the shallow clays, but could not be confirmed because of the use of mud rotary drilling methods. Well logs of subsurface lithology were prepared for all wells and lysimeters, along with well construction summaries, by on-site WESTON geologists and soil scientists; these are included in Appendix D.

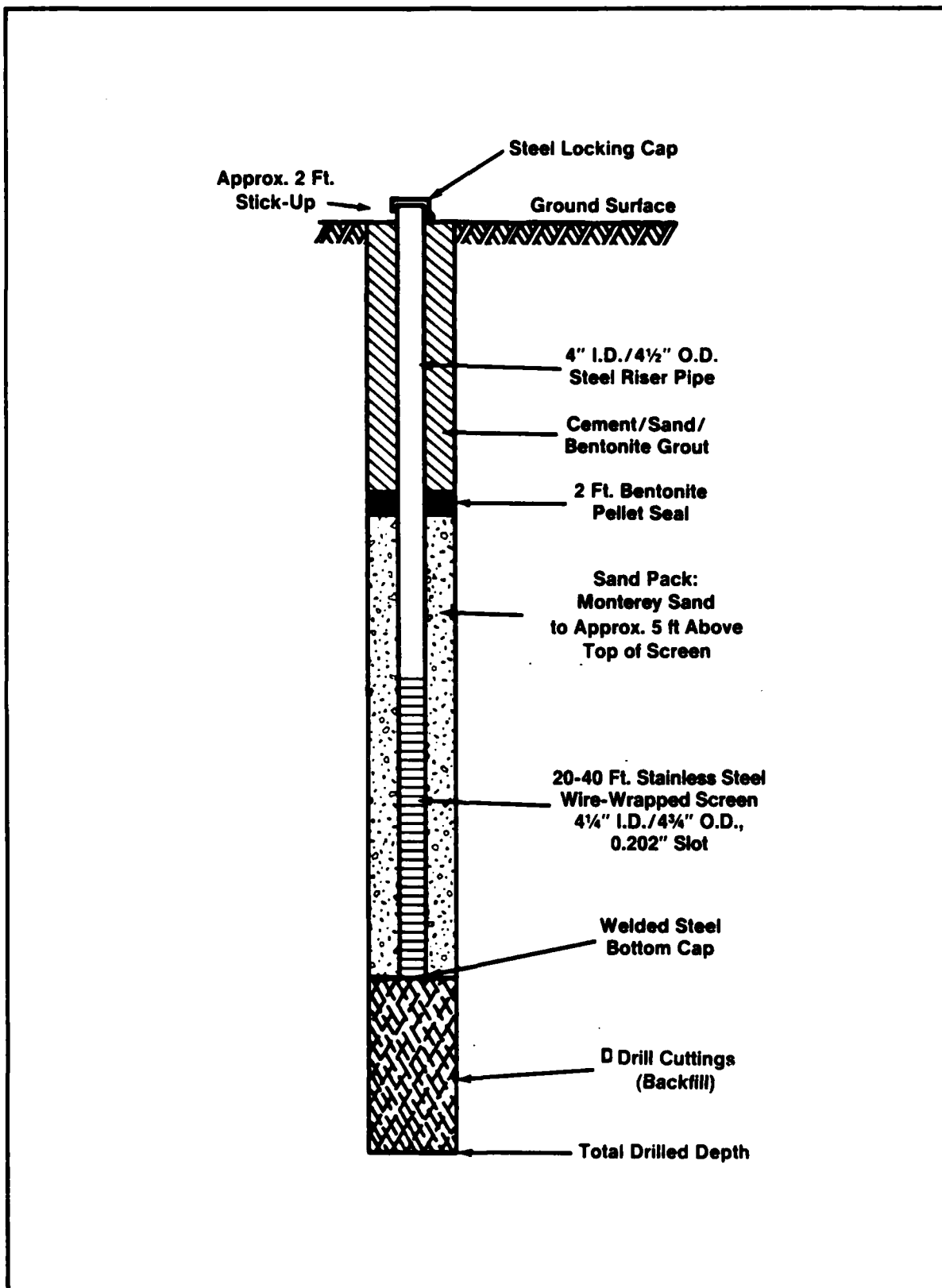
An HNu portable photonization detection unit or an organic vapor analyzer flame ionization detector were available at all times during the drilling operation for use by the on-site WESTON geologists and soil scientists (Subsection 3.1.1.6). The probe was held near the drilling fluid discharging at the well-head to record any atmospheric concentrations of volatile organics if present. No measurable concentrations were obtained from any of the borings.

Monitor wells were installed in boreholes held open with drilling mud. All wells were constructed of 21 to 42 feet of 4.25-inch ID/4.75-inch OD wire-wound stainless steel screen welded to 4-inch ID/4.5-inch OD low-carbon steel riser pipe. The screen slot size was 0.020 inch in all wells and screen length was 42 feet (nominal 40) in all but five monitor wells. Three wells (MW-290, MW-390, and MW-440) were constructed with 21 feet of screen, and two wells (MW-320 and MW-360) were constructed with 31 feet of screen. In general, an attempt was made to screen and sand-pack only the thickness of shallow aquifer sands and gravels where they occurred between a shallow (30 to 60 feet) and deeper (95 to 120 feet) clay layer. If no confining layers were encountered, a maximum of 42 feet of screen was installed.

In general, the holes were overdrilled by 10 to 20 feet to allow for some collapse of formation materials and settling of cuttings during well construction. The well screen was lowered to the desired depth, and packed in clean No. 2/16 Monterey sand. The sand pack was brought to approximately 5 feet above the top of the screen to ensure that the top of the screen would be well removed from the bentonite annular seal. The top of the sand pack was sealed with approximately 2 feet of bentonite pellets, and the remainder of the annulus was backfilled with a sandy ("9-sack") concrete grout containing bentonite in a 6:1 mix, installed by tremie methods.

The riser pipe was cut 2 to 3 feet above ground surface and fitted with a locking steel cap. A typical well construction diagram is shown in Figure 3-13. A summary of monitor well construction details is given in Table 3-5.

Following the completion of each well, drill cuttings in the mud pits were pumped out with a vacuum truck and removed to the hardfill area on the west end of LF-5. No field evidence of contamination (based on visual observation, odor, or organic vapor measurements) was found in the drill cuttings, and none were tested for hazardous properties. Each mud pit was filled in and the site was graded; the general area was restored as closely as possible to predrilling conditions.



**FIGURE 3-13 TYPICAL MONITOR WELL CONSTRUCTION**

Table 3-5  
Summary of Well Construction Details  
Castle Air Force Base

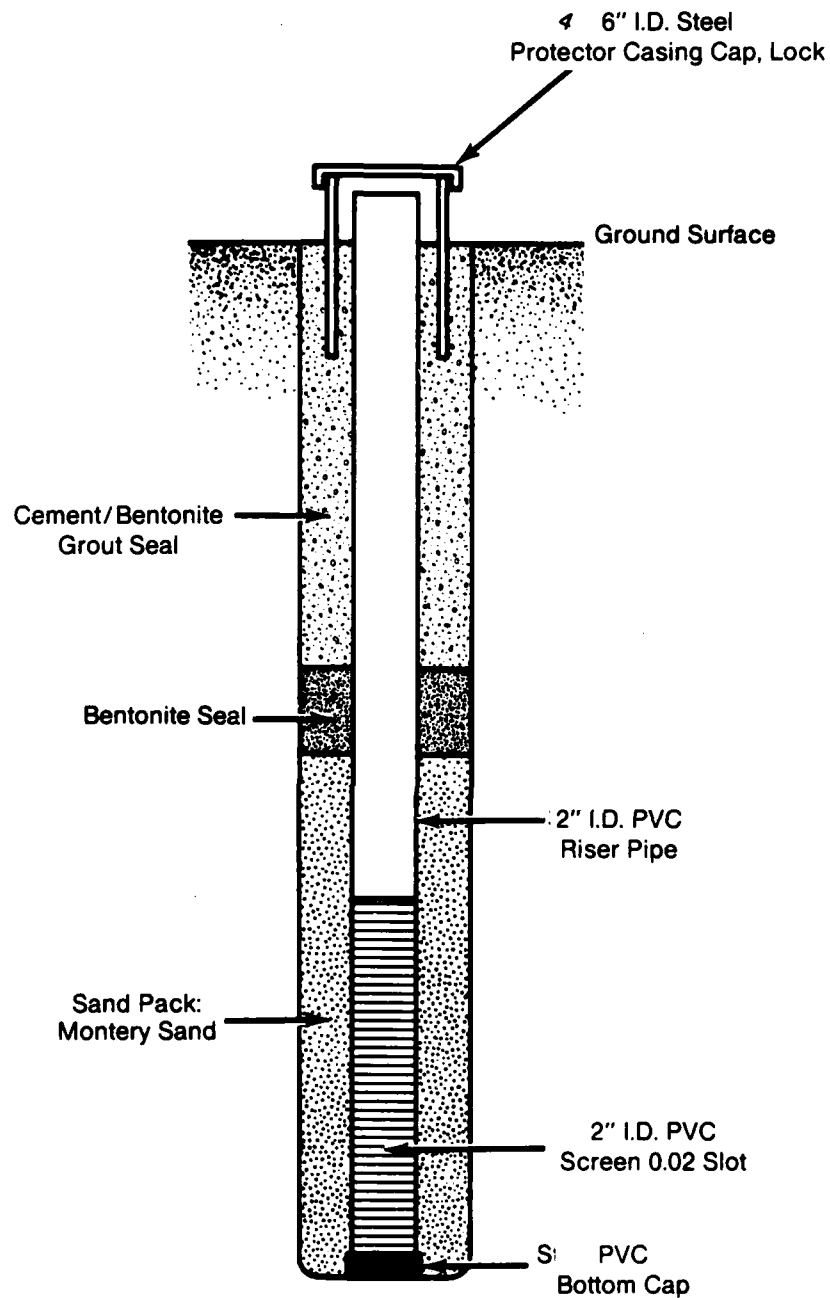
Well Number	Approximate Ground Surface Elevation (in feet)	Top of PVC Casing Elevation (in feet)	Screened Interval Below Ground Surface (in feet)	Sandpacked Interval Below Ground Surface (in feet)	Predominant Lithology in Screened Zone
MW-210	165.45	167.62	48-89	41-120	f-c GRAVEL and m-c sand
MW-220	164.32	166.18	48-89	43-100	f-c GRAVEL, c sand
MW-230	172.20	174.16	53-94	48-105	f-c SAND, little m-c gravel
MW-240	165.72	167.64	59-95	49-110	f-c SAND, trace m-c gravel
MW-250	168.89	171.01	52-92	47-105	f-c SAND, little m-c gravel, trace clay
MW-260	170.18	172.42	51-92	46-110	f-c SAND, trace m-c gravel
MW-270	168.14	170.56	48-89	42-105	f-c SAND, trace m-c gravel, trace clay
MW-280	167.32	169.36	48-89	34-100	f-c SAND, some m-c gravel, trace clay
MW-290	167.88	170.88	59-80	35-95	f-c SAND, some clay
MW-300	171.32	172.81	51-91	46-100	f-c SAND, some m-c gravel, trace clay
MW-310	167.03	168.88	47-87	42-105	f-c SAND, m-c gravel
MW-320	174.20	177.18	48-78	41-105	f-c SAND, little clay
MW-330	175.28	176.47	40-81	32-100	f-c SAND
MW-340	175.52	177.29	41-81	32-105	f-c SAND
MW-350	181.67	183.88	49-90	35-120	f-c SAND
MW-360	186.39	188.18	59-90	42-105	f-c SAND
MW-370	189.23	192.43	55-95	41-105	f-c SAND
MW-380	193.93	196.94	52-92	46-110	f-c SAND, little m-c gravel, trace clay
MW-390	192.36	195.15	81-102	74-120	m-c GRAVEL
MW-400	187.60	190.10	57-97	50-120	m-c GRAVEL, some f-c sand
MW-410	182.10	184.50	54-95	49-110	m-c GRAVEL, f-c sand
MW-420	182.54	184.73	57-97	50-120	f-c SAND, some m-c gravel, trace clay
MW-430	181.02	183.17	38-78	28-95	m-c GRAVEL, f-c sand
MW-440	177.23	178.93	77-97	72-120	f-c SAND, some m-c gravel
MW-450	178.44	180.13	54-95	49-105	f-c SAND, trace m-c gravel, trace clay
MW-460	181.25	184.05	56-96	50-110	f-c SAND, trace clay
MW-470	179.32	181.87	56-97	50-120	f-c SAND, trace clay

All monitor wells were developed first by surging and bailing with a 10-foot long steel bottom-loading bailer to loosen the mudpack deposited on the face of the formation, then by pumping with an electric submersible pump. The wells were pumped at an average rate of 6 gallons per minute for 1 to 3 hours each. All wells were pumped until discharge water was observed to be running clear at a maximum pumping rate of 6 gpm.

### 3.3.3.2 Lysimeter Construction

Eleven lysimeters were constructed in boreholes drilled using a hollow-stem auger rig. The boreholes were sampled every 5 feet with a 2-inch diameter, 18-inch long, split-spoon sampler following standard penetration procedures (ASTM D-1586). The soil samples were used for stratigraphic control and were not preserved for analysis. Samples were described by the on-site WESTON soil scientist; boring logs prepared on-site have been included in Appendix D. Final lysimeter depths were chosen based on the split-spoon soil samples. If a hard, compacted soil or hardpan was encountered, the boring was terminated and the lysimeter was installed.

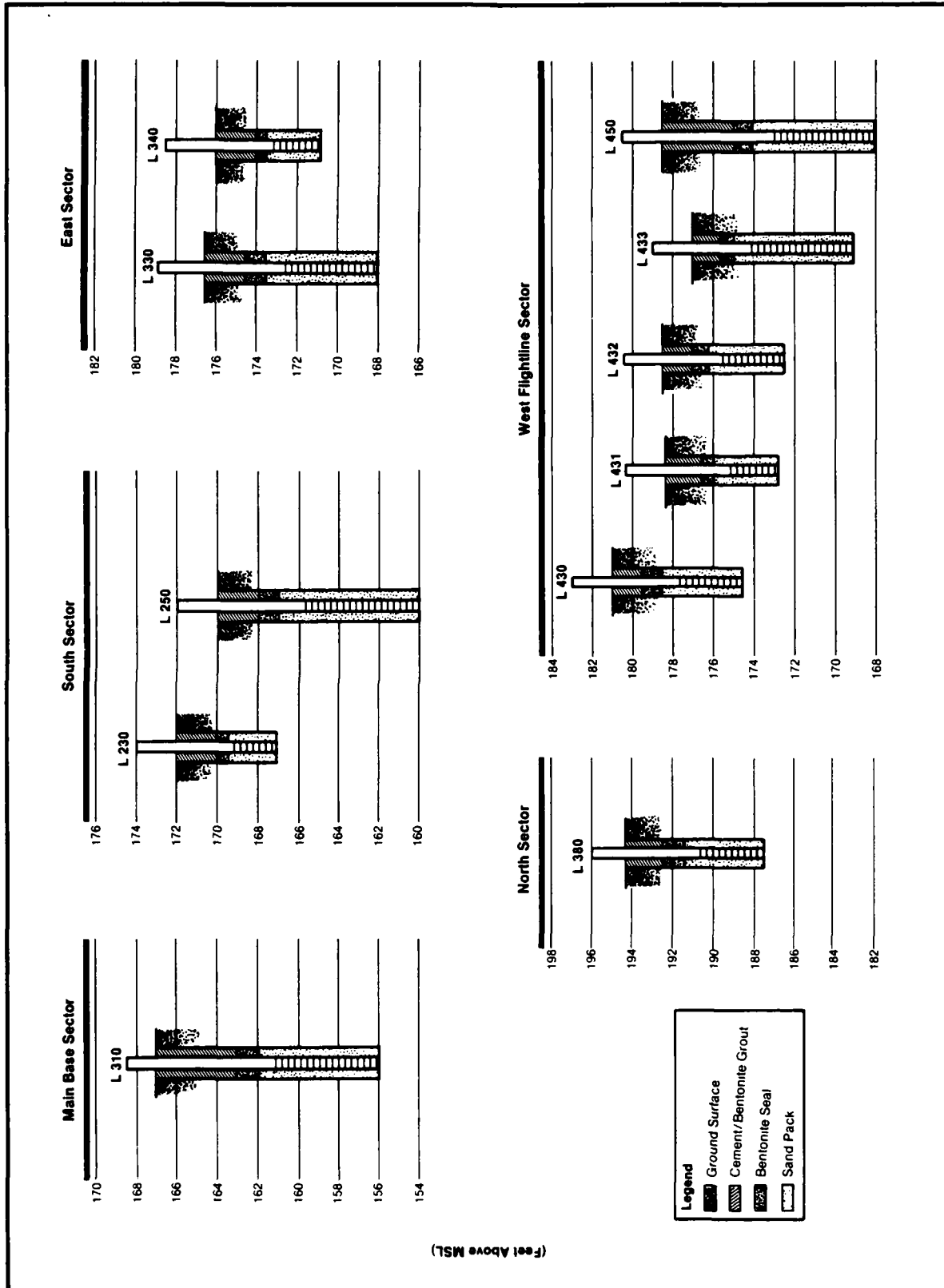
All lysimeters were constructed of 2 to 5 feet of 2-inch ID PVC screen threaded onto 2-inch ID PVC riser pipe. The screen slot size was 0.020 inches in all lysimeters. The well was lowered to the bottom of the open hole and packed in clean No. 2/16 Monterey sand. The sand pack was brought to approximately 1 foot above the top of the screen, then sealed with approximately 1 foot of bentonite pellets. The remainder of the annular space in all lysimeters was backfilled with a 6:1 cement/bentonite grout. Lysimeter construction was completed by installation of a 4-inch diameter steel security casing equipped with a steel cap and locking hasp. A diagram of a typical lysimeter construction is shown in Figure 3-14. A summary of lysimeter construction details is given in Table 3-6, and is shown schematically in Figure 3-15.



**FIGURE 3-14. TYPICAL LYSIMETER CONSTRUCTION**

Table 3-6  
Summary of Lysimeter Construction Details  
Castle Air Force Base

Well Number	Approximate Ground Surface Elevation (in feet)	Top of PVC Casing Elevation (in feet)	Screened Interval Below Ground Surface (in feet)	Sandpacked Interval Below Ground Surface (in feet)	Predominant Lithology in Screened Zone
L 230	171.94	173.96	2.8 - 4.8	2.5 - 4.8	Medium SAND
L 250	169.23	171.77	4.6 - 9.6	3.0 - 9.6	Fine-medium SAND
L 310	167.24	168.69	5.8 - 10.8	5.0 - 10.9	Fine-medium SAND
L 330	176.30	178.83	3.8 - 8.8	2.5 - 8.8	Fine-medium SAND
L 340	176.09	178.59	3.2 - 5.2	3.0 - 5.2	Medium SAND, with silt
L 380	194.27	196.76	3.2 - 6.2	2.5 - 6.2	Medium SAND
L 430	180.79	182.83	3.4 - 6.4	2.0 - 6.4	Fine - medium SAND
L 431	177.86	180.21	3.2 - 5.2	2.5 - 5.2	Fine SAND
L 432	177.95	180.30	2.6 - 5.6	2.5 - 5.6	Fine - medium SAND
L 433	177.22	179.02	3.9 - 8.9	8.0 - 8.9	Medium SAND
L 450	178.62	180.35	5.7 - 10.7	4.5 - 10.7	Medium SAND



**FIGURE 3-15 LYSIMETER CONSTRUCTION SUMMARY**

### 3.3.3.3 Soil Borings

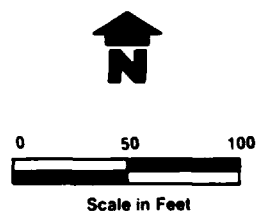
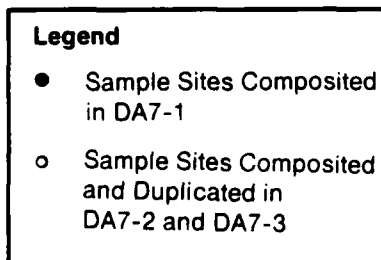
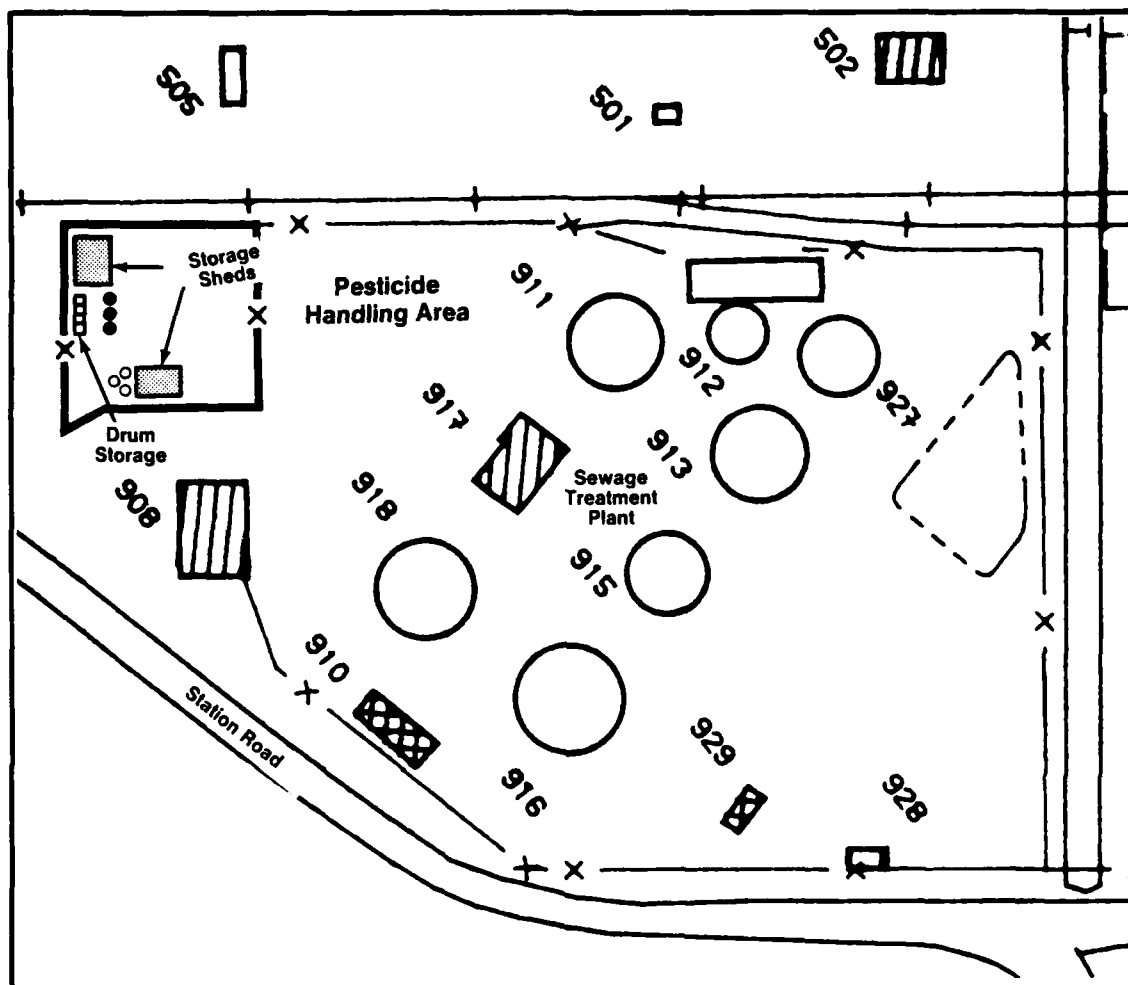
A total of six soil borings were drilled at two sites: DA-1 (Figure 3-5) and DA-4 (Figure 3-12). Each soil boring was advanced using a hollow-stem auger, and sampled continuously with a 2-inch diameter, 18-inch long, split-spoon sampler following standard penetration test procedures (ASTM D-1586). The soil samples were collected every 1-foot interval to 10 feet. The split-spoon sampler was decontaminated with a detergent solution and rinsed in clear water between each sample. The sampler was fitted with four previously decontaminated 2-in. by 4-in. brass ring inserts, then reassembled. The split-spoon sampler was driven to the appropriate depth interval, then recovered, opened, and the brass rings removed with as little disturbance as possible. The samples collected from the 0 to 1, 4 to 5, and 9 to 10 foot intervals were preserved for immediate analysis. Samples from the remaining 1-foot intervals were also collected and archived for analysis at a later date, if necessary. Duplicate samples for immediate analysis were taken by redrilling and coring the 0 to 1.5 interval in a new hole immediately adjacent to the first.

The analytical protocols for the two sites are given in Table 3-2. Additional detail on the intervals sampled, analytes, and sample designation is available in Part I of the Field Sampling and QA/QC Plan (Appendix G). The brass rings that were used for collection of VOA samples were capped on both ends with Teflon sheeting, then covered by tightly-fitted plastic caps, and labeled appropriately. Samples for oil and grease or pesticides and herbicides were collected from the brass rings by pushing the soil out with a stainless steel spatula into a clean labeled glass quart jar with Teflon-lined lid. The soil samples from the remaining intervals were archived by placing one sealed and capped brass ring in a clean labeled pint glass jar, and later placing the jars in storage.

Upon completion of sampling, each boring was backfilled with drill cuttings from the hole.

### 3.3.3.4 Surface Soil Sampling

Hand surface soil samples were taken at Discharge Area 7, the pesticide/herbicide storage and handling area. The procedure for sampling in this area was outlined in Part I of the Field Sampling and QA/QC Plan (Appendix G). Individual samples were collected from the top few inches of soil in six locations as shown in Figure 3-16, and composited into three samples for analysis using stainless steel utensils and bowl. The three samples for analysis were stored in clean glass quart jars with Teflon-lined lids.



**FIGURE 3-16 SURFACE SOIL SAMPLING LOCATIONS, MAIN BASE SECTOR**

### 3.3.3.5 Drainage Ditch Sediment Sampling

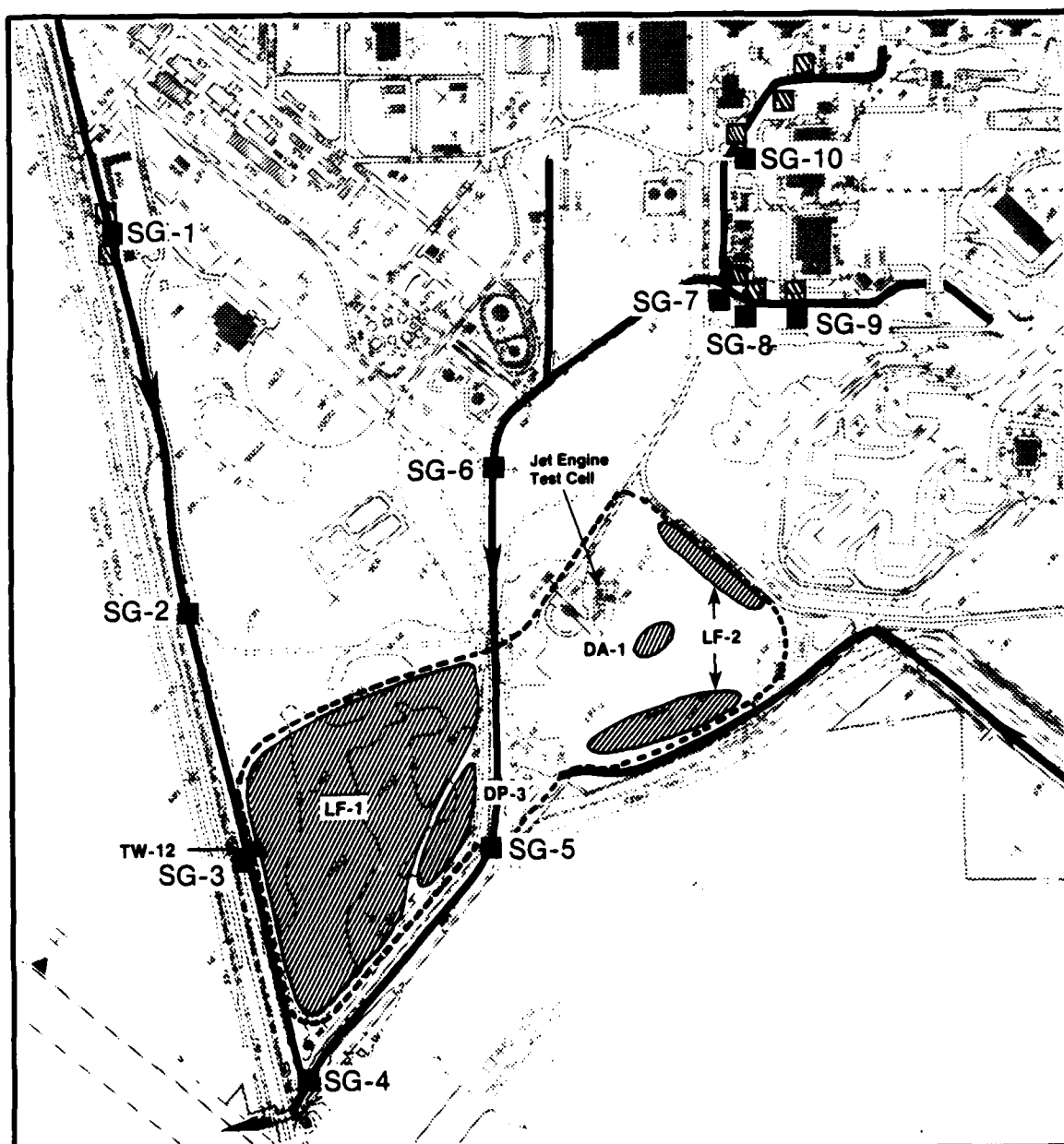
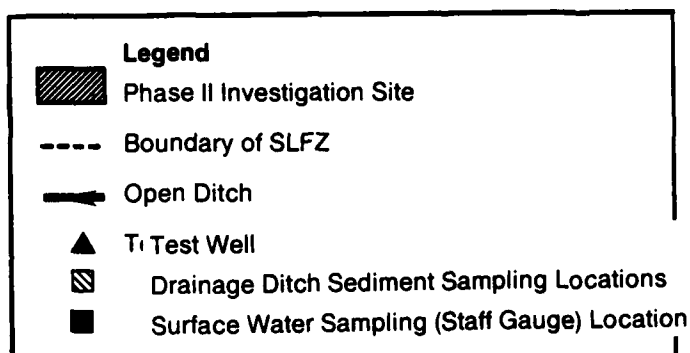
Samples of bottom sediment from the drainage ditches were collected from eight locations associated with DA-8, DA-5, and DA-3, all in the Main Base Sector. Sampling protocols for these sites are summarized in Table 3-2. Sediment sampling locations are shown, along with staff gage locations, in Figure 3-17.

Samples were collected using a split-spoon sampler fitted with brass ring inserts as described in Subsection 3.3.4. The sampler was threaded to a 20-foot length of drill rod, connected to the boom of the development rig, and driven using a standard penetration test hammer and the rig pulley. At each location, the sampler was driven twice, to recover separate samples from the 0- to 1- and 1- to 2-foot intervals. Duplicates of selected samples were collected by coring the 0- to 1-foot interval in a new location immediately adjacent to the sample location being duplicated. The procedure for preserving the samples was the same as described in Subsection 3.3.4. The split-spoon sampler was decontaminated with a detergent solution and clear rinse between locations and between samples at a single location.

### 3.3.4 Surface Geophysical Surveys

Between 28 November and 12 December 1984, WESTON conducted geophysical surveys at three sites: DA-8 in the Main Base Sector, DA-3 in the South Sector, and LF-5 in the North Sector. Geophysical mapping at each site resulted from the use of two complimentary geophysical methods: ground penetrating radar (GPR) and magnetometry. Data generated from the two methods were used in a congruent manner to meet survey objectives.

At DP-3 and LF-5, the objectives of the combined GPR and magnetometer surveys, as stated in the Task Order, were to outline the areal extent of pits, trenches, and/or fill material and to determine the presence or absence of buried drums. At DA-8 the objective of the survey was to establish the location of the former overflow discharge line connecting Building 1550 to the drainage ditch. A preliminary review of appropriate aerial photographs and Base documents was made prior to the field surveys to direct the survey at each site and to design the orientation and spacing of the grid.



**FIGURE 3-17 DRAINAGE DITCH SEDIMENT AND  
SURFACE WATER SAMPLING LOCATIONS**



The following subsections review field methodologies and analytical techniques used in the collection and interpretation of GPR and magnetometer data, and the specific methodologies as applied to each of the three sites.

#### 3.3.4.1 GPR Survey, Methodology, and Analysis

WESTON conducted GPR surveys of the three sites using a GSSI systems 8 ground radar unit. Surveying was accomplished by towing a wheel-mounted radar receiver/transmitter (R/T) antenna across a pre-determined survey grid. The antenna transmits an electromagnetic pulse and receives a continuous stream of reflected pulses composed of surface reflections and reflections of interfaces encountered by the transmitted pulse at depth. The received signal is transmitted to a radar control unit connected to a portable printer, so that a real-time printed profile is obtained for each traverse.

Contrasts in soil structure or chemical properties that effect the electrical conductivity of the soil will show as contrasts on the printed profile. Discrete metal objects, such as pipes or drums, show as single targets with characteristic signatures in the background profile. An experienced operator can enhance the radar signal and quality of the printouts by processing signals through the radar control unit to fine-tune the system at each site.

At each site, or more frequently if significant areal variations in soil type are expected, the GPR system is calibrated. To calibrate the system, either the dielectric constant ( $E_r$ ) of the survey medium or the depth to a particular object or interface must be known. In general, a two-step process was followed to calibrate the system at each of the sites at CAFB. In a first step, a theoretical calibration was performed based on the dielectric constant corresponding to site-specific soil and moisture conditions. Then, a profile was run over a pipe or culvert at a known depth (measured in a manhole or ditch) to accurately define the vertical scale.

Analysis of GPR data involves an interpretation of each individual profile, and a comparison and cross-check of the collective results. The interpretation process has two principal objectives:

- Apply specific knowledge of known signature densities and configurations to the identification of pipes, drums, trenches, soil structures, discontinuities, and surface disturbances.

- Identify trends and conditions by comparing standard profiles one to another. This process identifies continuity in stratified soil interfaces, buried utilities, and groundwater data.

#### 3.3.4.2 Magnetometer Survey Methodology and Analysis

The vertical field flux gate magnetometer consists of an element sensitive to natural geomagnetic fields emanating vertically from the earth's surface. The instrument is transistorized, and measurements of the vertical magnetic field are read from a meter. The instrument is hand-held and leveled at each location using a built-in circular bubble level. The instrument used in surveys at CAFB was a Geonics Model No. MF-2.

Magnetometer surveys of a site are performed by laying out a control grid on the site and taking a single measurement at each node in the grid. Prior to the survey, the instrument is field-calibrated by setting it to a relative zero representing ambient magnetic conditions. At each site, a Base station outside the survey area, but having similar subsoils is designated, and readings are taken at the Base station approximately every half hour during the survey. This serves to document natural periodic fluctuations in the ambient field over time at a single background point.

In the data reduction process, the background magnetic field, including any diurnal variations, is subtracted from the data collected in the site survey, and the resultant data array represents the magnitude of variation at each node from the ambient magnetic field. These data, when contoured, yield a magnetic anomaly map in which highs and lows represent areas exhibiting the greatest degree of variation from background.

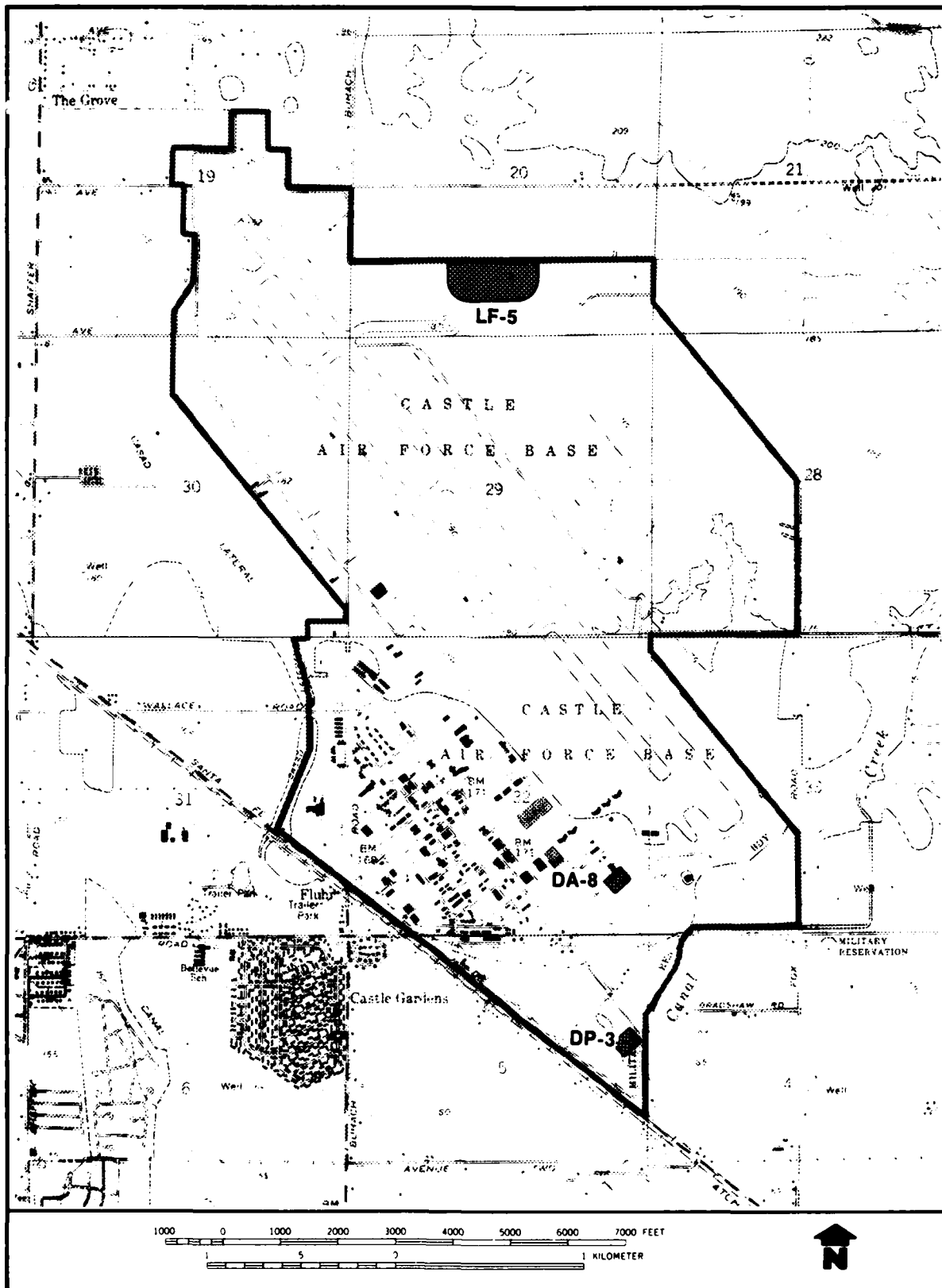
Magnetic data can be used to provide a semiquantitative measure of the distribution of magnetic anomalies produced by magnetic sources in the earth. Unlike GPR data, however, these magnetic data are not depth-specific. The two types of data are used in a complimentary manner to locate areas of subsurface disturbance and concentrations of buried metal objects on an areawide basis, as indicators of the extent of a landfill area, or locally to trace a single pipe.

#### 3.3.4.3 Site-Specific Methodologies

A location map for the three geophysical survey sites, DA-8 (Building 1550), DP-3 (in the SLFZ), and LF-5, is given in Figure 3-18. Individual grid maps for each of the sites are shown in Figures 3-19, 3-20, and 3-21.

The site map for DA-8 was developed from field measurements in the areas between Building 1550 and the ditch. Accurate geophysical measurements could not be made within 25 feet of Building 1550 due to the presence of overhead telephone lines, electrical utilities, and a buried sewer pipe running parallel to the building. The survey concentrated on the area of a paved parking lot and a lawn south of the building up to the edge of the ditch. The grid was oriented parallel to the side of the building so as to intersect the most likely path of a pipe running between the building and the ditch. GPR traverses were made in an approximate east-west direction approximately 30 feet apart. The GPR was calibrated over the sewer pipe running parallel to Building 1550. The magnetometer measurements were collected at 12.5-foot intervals along each of the four traverse lines. The Base station for the magnetometer measurements was located next to the ditch as shown in Figure 3-19.

The site map for DP-3 was developed from the preliminary 1984 Comprehensive Base Layout topographic plan, on which were superimposed sprinkler locations from a photograph of the sprayfield area. In addition, the 1952-1954 topographic maps of the Base were reviewed, revealing an old barrow pit that had been located in the approximate area of DP-3. This barrow pit has been shown in Figure 3-20, located approximately from the 1952-1954 topographic map. The survey grid over DP-3 was oriented according to the sprinkler head layout: GPR traverses were run parallel and perpendicular to the buried PVC sprinkler supply lines, approximately 60 feet apart. Magnetometer measurements were taken at approximately 60-foot intervals along the same survey lines. The GPR was calibrated over culverts under the bridge crossing the ditch. The Base station for DP-3 is shown in Figure 3-20.



**FIGURE 3-18 GEOPHYSICAL SURVEY SITES LOCATION MAP**

The site map for LF-5 was developed from an aerial photograph after extensive field verification. This preliminary work enabled delineation of trenches outlined by obvious subsidence cracks, as well as an old impoundment, areas of mounding including an area of near-surface buried drums, and areas of bulldozer activity (scraping and grading) as shown in Figure 3-21. From this preliminary survey, individual GPR grids were keyed to each of the individual major trenches and areas of earth mounding. It was felt that this system would provide most efficient use of the geophysical methodologies to locate those trenches with obvious concentrations of buried metallic objects. While the GPR survey concentrated principally on the trenches and one area of mounding, the magnetometer survey grid was extended to provide good coverage of the whole landfill area. The hardfill areas on the west end of LF-5 were excluded from the survey due to the great surface irregularity in the areas which would have prevented collection of meaningful data. The GPR was calibrated over a culvert in the northeast end of the landfill. The magnetometer Base station for LF-5 is shown in Figure 3-21.

### 3.3.5 Water Sampling Program

The water sampling program at CAFB included two rounds of water level measurements and sampling at all available surface- and groundwater sampling stations, to include 9 staff gage (surface water) stations, 11 Base production wells, 8 existing test wells, 27 new monitor wells, and 11 lysimeters. Specific sampling requirements for each station and protocols to be followed in the water sampling program were detailed in Part 2 of the Field Sampling and QA/QC Plan, provided in Appendix G. The first round of groundwater sampling was conducted between 23 January and 1 February 1985. The first round of surface water sampling had to be delayed because water pumped nightly from production well 3 (PW-3) was discharged to the southwest perimeter ditch. The first round of surface water samples was collected on 4 March 1985, approximately 1 week after pumping from PW-3 had ceased. The second round of both surface and groundwater samples was collected between 1 April and 12 April 1985.

#### 3.3.5.1 Staff Gage Installation

A total of 10 staff gages (designated SG-1 through SG-10) were installed in drainage ditches at CAFB. Locations are shown in Figure 3-17. Staff gage SG-10, located in the ditch adjacent to a monitor well-lysimeter pair (MW-310 and L-310), was used for water level measurements only. The other nine staff gages (SG-1 through SG-9) were used for water level measurements and as permanent markers for surface water sampling stations. Three staff gages (SG-7, SG-8, and SG-9) were located adjacent to and downstream from Building 1550 (at the approximate location of DA-8), and were coincident with the ditch sediment sampling stations for DA-8. Six staff gages associated with the SLFZ were located to provide good coverage of the two drainage ditches converging on the surface water outlet at the southern Base boundary corner. Three of them, SG-1 through SG-3, were installed in the western ditch paralleling Santa Fe Boulevard. The location of SG-1 corresponds to the downstream sediment sampling location for DA-3; SG-2 is adjacent to the northwest corner of LF-1; and SG-3 is opposite TW-12. The three staff gages in the southeastern ditch were installed at the old railroad bridge (SG-6) at the southwest corner of LF-1 (SG-5) and at the southern tip of LF-1 at the confluence of the two ditches (SG-4).

Each staff gage consisted of a 1-inch ID black iron pipe approximately 5 feet long, to which stadia rod facing tape graduated in 0.02 foot was affixed with waterproof clear tape. The rods were driven manually with a sledgehammer 1.5 to 2.5 feet into the ditch bottom, or until hardpan prevented further penetration. Each staff gage station was labeled with a painted metal sign.

### 3.3.5.2 Water Level Elevation Survey

Shortly after well completion and staff gage installation, WESTON subcontracted a California registered surveyor from Larsen, Ohlinger and Hill, Inc. of Merced, California, to survey the elevations of 67 points at CAFB. The survey was performed between 14 and 20 December 1984, and all elevations were measured relative to a single USGS benchmark on the parade ground near the Main Gate. The elevation of this benchmark relative to the U.S. Geodetic Vertical Datum is given by Base records as 167.792 feet.

On the new monitor wells and lysimeters, a point was marked off on the top of the steel casing; this was the point surveyed. All water level measurements were made from that point. On the existing test wells with dedicated pumps, the top of the metal plate sealing the well was surveyed, and all water level measurements were made relative to the top of the metal plate through the access point provided. The elevations reported in the Phase I report and given on the signs next to these test wells were not the same as the elevations surveyed in this investigation. The elevation reported earlier may have referred to some other measuring point, such as the top of the discharge tubing.

At the production wells and TW-19, a spot was painted and surveyed on the uppermost concrete platform if the pump motor was raised on a pedestal, or on the concrete floor near the pump motor base if no pedestal existed.

At the surface-water monitor stations, the top of the staff gage pole was surveyed, and the elevation of a convenient reference point within the arbitrary scale of the staff gage was also measured. Although the staff gage poles were driven 1.5 to 2.5 feet into the ditch bottom, in some cases the ditch bed may not have been very stable, and the staff gages may have moved slightly after the survey. For this reason, the staff gage elevations given should be considered only approximate.

Elevation survey results, including measuring point elevations and approximate ground surface elevations, are summarized in Tables 3-7 and 3-8.

Table 3-7

Groundwater Survey Station Elevations

<u>Survey Number</u>	<u>Station Description</u>	<u>Measuring Point Elevation (Feet above MSL)</u>	<u>Casing Stick-up (feet)</u>	<u>Ground Surface Elevation (Feet above MSL)</u>
MW-210	Top of steel casing	167.617	2.17	165.45
MW-220	Top of steel casing	166.182	1.86	164.32
MW-230	Top of steel casing	174.162	1.96	172.20
MW-240	Top of steel casing	167.642	1.92	175.72
MW-250	Top of steel casing	171.007	2.12	168.88
MW-260	Top of steel casing	172.417	2.24	170.18
MW-270	Top of steel casing	170.557	2.42	168.14
MW-280	Top of steel casing	169.357	2.04	167.32
MW-290	Top of steel casing	170.882	3.00	167.88
MW-300	Top of steel casing	172.807	1.49	171.32
MW-310	Top of steel casing	168.882	1.85	167.03
MW-320	Top of steel casing	177.175	2.98	174.20
MW-330	Top of steel casing	176.465	1.19	175.28
MW-340	Top of steel casing	177.285	1.77	175.52
MW-350	Top of steel casing	183.880	2.21	181.67
MW-360	Top of steel casing	188.180	1.79	186.39
MW-370	Top of steel casing	192.430	3.20	189.23
MW-380	Top of steel casing	196.940	3.01	193.93
MW-390	Top of steel casing	195.145	2.79	192.36
MW-400	Top of steel casing	190.095	2.50	187.60
MW-410	Top of steel casing	184.500	2.40	182.10
MW-420	Top of steel casing	184.725	2.19	182.54
MW-430	Top of steel casing	183.170	2.15	181.02
MW-440	Top of steel casing	178.927	1.70	177.23
MW-450	Top of steel casing	180.130	1.69	178.44
MW-460	Top of steel casing	184.050	2.80	181.25
MW-470	Top of steel casing	181.865	2.55	179.32

Table 3-7  
(continued)

<u>Survey Number</u>	<u>Station Description</u>	<u>Measuring Point Elevation (Feet above MSL)</u>	<u>Casing Stick-up (Feet)</u>	<u>Ground Surface Elevation (Feet above MSL)</u>
L-230	Top of steel casing	173.962	2.02	171.94
L-250	Top of steel casing	171.767	2.54	169.23
L-310	Top of steel casing	168.687	1.45	167.24
L-330	Top of steel casing	178.825	2.53	176.30
L-340	Top of steel casing	178.585	2.50	176.09
L-380	Top of steel casing	196.760	2.49	194.27
L-430	Top of steel casing	182.825	2.03	180.80
L-431	Top of steel casing	180.210	2.35	177.86
L-432	Top of steel casing	180.300	2.35	177.95
L-433	Top of steel casing	179.020	1.80	177.22
L-450	Top of steel casing	180.350	1.73	178.62
TW-12	Top of metal plate	167.852	1.00 <sup>(1)</sup>	167
TW-13	Top of metal plate	167.797	1.00 <sup>(1)</sup>	167
TW-14	Top of metal plate	167.932	1.00 <sup>(1)</sup>	167
TW-15	Top of metal plate	166.577	1.00 <sup>(1)</sup>	166
TW-16	Top of metal plate	171.827	1.00 <sup>(1)</sup>	171
TW-17	Top of metal plate	167.492	1.00 <sup>(1)</sup>	166
TW-18	Top of metal plate	171.234	1.00 <sup>(1)</sup>	170
TW-19	Top of uppermost concrete slab	179.660	1.00 <sup>(1)</sup>	179

(1) Visual Estimate

Table 3-7  
(continued)

<u>Survey Number</u>	<u>Station Description</u>	<u>Measuring Point Elevation (Feet above MSL)</u>	<u>Casing Stick-up (feet)</u>	<u>Ground Surface Elevation (Feet above MSL)</u>
PW-1	Paint spot on concrete floor	166.092	0	166.09
PW-2	Paint spot on concrete floor	166.627	0	166.63
PW-3	Paint spot on concrete floor	167.022	0	167.02
PW-4	Paint spot on concrete floor	168.042	0	168.04
PW-5	Top of concrete pedestal	177.995	3.00 <sup>(1)</sup>	175
PW-6	Top of concrete pedestal	180.115	3.00 <sup>(1)</sup>	178
PW-7	Paint spot on concrete floor	170.042	0	170.04
PW-8	Paint spot on concrete floor	169.967	0	169.97
PW-9	Top of concrete pedestal	169.827	2.00 <sup>(1)</sup>	168
PW-11	Paint spot on concrete floor	177.375	0	177.38
New PW	Top of concrete pedestal	168.262	2.00 <sup>(1)</sup>	166

(1) Visual Estimate

Table 3-8

Surface Water Survey Station Elevations

<u>Survey Station No.</u>	<u>Reference Point</u>	<u>Reference Point Elevation (feet above MSL)</u>	<u>Top of Pole Elevation (ft above MSL)</u>
SG 1	2.00	163.642	164.022
2	7.00	163.307	164.357
3	4.00	163.777	164.167
4	2.00	162.632	162.862
5	9.00	161.987	162.767
6	7.00	162.687	163.547
7	9.00	164.427	165.717
8	3.00	164.202	165.242
9	5.00	164.637	165.657
SG 10	6.00	165.067	165.197

The most complete early round of water level measurements was made shortly after completion of the new monitor wells on 18 and 19 December 1984. Additional rounds of water level measurements were made on 5 December 1984, 21 January, 1 February, 1 April, and 10 and 11 April 1985, and included all accessible monitor stations. Water levels in wells were measured using an electric water level probe. In general, water level measurements in the production wells were difficult, due to inaccessibility of the well casing, poor calibration of the air line, and/or presence of oil on the water surface. The most reliable water level measurements in production wells were obtained on 18 and 19 December 1984 from PW-9, PW-11, and the new production well, where the well casing could be accessed directly with the water level probe. Measuring point elevations and depth-to-water measurements in wells are given in Table 3-9 and surface water measurements in Table 3-10. Lysimeters have not been included, although they were measured in each round. All lysimeters were found to be dry at all times, except L-310, which had 1.34 feet of water in the bottom on 19 December, but was dry by the first sampling round in late January. Water level data for 18-19 December 1984 and 10-11 April 1985 have been converted to water level elevations using the surveyed elevations and these elevations are reported in Table 3-11.

#### 3.3.5.3 Groundwater Sampling

WESTON conducted two rounds of groundwater sampling, between 22 January and 1 February 1985 and 1 April and 12 April 1985. General sampling protocols are listed by site in Table 3-2, and specific sampling requirements for each groundwater sampling station, determined from the task order, are listed in the Field Sampling and QA/QC Plan (Appendix G). A total of 57 groundwater stations were designated for sampling, including 11 Base production wells, 8 existing test wells, 27 new monitor wells, and 11 lysimeters. During the first round, two Base production wells (PW-4 and PW-9) were not operational and, therefore, were not sampled, and all 11 lysimeters were dry. A total of 44 production stations were sampled in the first round. During the second round, PW-9 could not be sampled and all 11 lysimeters were dry. A total of 45 groundwater stations were sampled in the second round.

Table 3-9

Groundwater Level Data  
December 1984 - April 1985

Well Number	Meas- uring Point Elev. (feet MSL)	Depth to Water					
		5	18-19	21	1	1	10-11
		Dec 1984	Dec 1984	Jan 1985	Feb 1985	April 1985	April 1985
MW-210	167.62	35.78	35.69	35.79	35.91	35.18	35.48
MW-220	166.18	33.72	33.48	33.57	33.85	32.91	33.27
MW-230	174.16	34.82	34.73	35.94	36.18	35.92	36.27
MW-240	167.64	29.68	29.64	29.98	30.00	30.23	30.24
MW-250	171.01	33.92	33.85	33.80	33.87	34.06	34.09
MW-260	172.42	35.30	35.22	35.29	35.32	35.51	35.59
MW-270	170.56	34.43	34.55	34.51	34.53	34.48	34.56
MW-280	169.36	33.70	33.53	33.51	33.58	33.52	33.66
MW-290	170.88	35.74	35.54	35.46	35.51	35.39	35.49
MW-300	172.81	NA	38.25	38.10	38.16	37.92	38.01
MW-310	168.88	34.36	34.30	34.19	34.19	33.98	34.06
MW-320	177.18	42.40	42.12	41.88	41.74	41.47	41.74
MW-330	176.47	42.41	42.19	41.82	41.74	41.28	41.46
MW-340	177.29	43.21	42.92	42.62	42.49	42.00	42.21
MW-350	183.88	50.57	50.27	49.88	49.74	49.28	49.40
MW-360	188.18	54.67	54.48	53.98	53.80	53.39	53.48
MW-370	192.43	58.78	58.59	58.07	58.00	57.57	57.64
MW-380	196.94	63.06	62.97	62.43	62.38	62.08	62.32
MW-390	195.15	60.35	60.27	60.22	60.17	60.57	61.37
MW-400	190.10	55.57	55.46	55.34	55.40	55.78	56.78
MW-410	184.50	50.17	50.09	50.10	50.05	50.47	51.17
MW-420	184.73	51.20	51.16	51.08	51.08	51.16	51.70
MW-430	183.17	50.00	49.86 <sup>1</sup>	NA	NA	NA	49.76
MW-440	178.93	46.23	46.12	45.96	45.92	45.66	45.89
MW-450	180.13	47.14	47.00	46.91	46.92	46.96	47.38
MW-460	184.05	48.00	47.87	47.54	47.53	47.02	47.37
MW-470	181.87	46.63	46.32	46.02	45.97	45.47	45.68

Table 3-9  
(continued)

Well Number	Meas- uring Point Elev. (feet MSL)	Depth to Water					
		5 Dec 1984	18-19 Dec 1984	21 Jan 1985	1 Feb 1985	1 April 1985	10-11 April 1985
TW-12	167.85	NA	30.67 <sup>2</sup>	30.67	30.68	30.61	30.67
TW-13	167.80	NA	33.98	33.98	34.22	33.69	33.94
TW-14	167.93	NA	35.41	35.35	35.62	34.94	35.21
TW-15	166.58	NA	32.17	32.16	32.30	31.97	32.24
TW-16	171.83	NA	38.35	38.30	38.48	37.97	38.15
TW-17	167.49	NA	34.57	34.72	34.89	34.00	34.32
TW-18	171.23	NA	38.35	38.31	38.45	37.92	38.12
TW-19	179.66		45.47	NA	45.24	44.60	44.98
PW-1	166.09	NA	91 <sup>3</sup> , <sup>4</sup>	NA	NA	NA	NA
PW-2	166.63	NA	46 <sup>3</sup>	NA	NA	NA	NA
PW-3	167.02	NA	36.55	NA	NA	NA	NA
PW-4	168.04	NA	48 <sup>3</sup>	NA	NA	NA	NA
PW-5	178.00	NA	50 <sup>3</sup>	NA	NA	NA	NA
PW-6	180.12	NA	50 <sup>3</sup>	NA	NA	NA	NA
PW-7	170.04	NA	100 <sup>3</sup> , <sup>4</sup>	NA	NA	NA	NA
PW-8	169.97	NA	NA	NA	NA	NA	NA
PW-9	169.83	NA	36.95	NA	NA	NA	NA
PW-11	177.38	NA	42.55	NA	NA	NA	NA
New PW	168.26	NA	35.90	NA	36.70	36.08	51.70 <sup>4</sup>

<sup>1</sup>Measured 5 December 1984, adjusted for time difference.

<sup>2</sup>Measured 21 January 1985, adjusted for time difference.

<sup>3</sup>Approximate measurement, using airline method.

<sup>4</sup>Pumping level (all other levels are static).

<sup>5</sup>Average static level for period from November 1984 to January 1985.

NA -- Well not accessible for measurement.

Table 3-10

Surface Water Level Data  
December 1984 - April 1985

Station	Refer- ence Point Eleva- tion	Refer- ence Point	Water Level Reading				
			19 Dec 1984	21 Jan 1985	1 Feb 1985	1	11
						April 1985	April 1985
SG-1	163.64	2.00	0.50	1.33	0.71	0.20	Dry
SG-2	163.31	7.00	6.02	6.71	6.16	6.00 <sup>1</sup>	Dry
SG-3	163.78	4.00	---	2.86	2.34	2.13	Dry
SG-4	162.63	2.00	0.41	1.00	0.60	0.56	0.61
SG-5	161.99	9.00	8.09	8.66	8.26	8.23	8.30
SG-6	167.69	7.00	6.41	6.40	6.40	6.40	6.48
SG-7	164.43	9.00	7.67	7.67	7.66	7.64	7.76
SG-8	164.20	3.00	---	2.00 <sup>1</sup>	1.90 <sup>1</sup>	2.80 <sup>1</sup>	2.08 <sup>1</sup>
SG-9	164.64	5.00	3.30	3.40 <sup>1</sup>	3.40 <sup>1</sup>	2.90 <sup>1</sup>	3.48
SG-10	165.07	6.00	4.39	4.41	4.40	4.38	4.39

<sup>1</sup>Visual estimate.

Table 3-11

Water Level Elevations  
18 and 19 December 1984 and 10 and 11 April 1985

Monitor Station Number	18-19 Dec 1984	20-22 April 1985
MW-210	131.93	132.14
MW-220	132.70	132.91
MW-230	139.43	137.89
MW-240	138.00	137.40
MW-250	137.16	136.92
MW-260	137.20	136.83
MW-270	136.01	136.00
MW-280	135.83	135.70
MW-290	135.34	135.39
MW-300	134.56	134.80
MW-310	134.58	134.82
MW-320	135.06	135.44
MW-330	134.28	135.01
MW-340	134.37	135.08
MW-350	133.61	134.48
MW-360	133.70	134.70
MW-370	133.84	134.79
MW-380	133.97	134.62
MW-390	134.88	133.78
MW-400	134.64	133.32
MW-410	134.41	133.33
MW-420	133.57	133.03
MW-430	133.31	133.41
MW-440	132.81	133.04
MW-450	133.13	132.75
MW-460	136.18	136.68
MW-470	135.55	136.19

Table 3-11  
(continued)

Monitor Station Number	18-19 Dec 1984	20-22 April 1985
TW-12	137.18	137.18
TW-13	133.82	133.86
TW-14	132.52	132.72
TW-15	134.41	134.34
TW-16	133.48	133.68
TW-17	132.92	133.17
TW-18	132.88	133.11
TW-19	134.19	134.68
PW-1	75 <sup>1</sup>	NA
PW-2	120 <sup>1</sup>	NA
PW-3	130.5 <sup>1</sup>	NA
PW-4	120 <sup>1</sup>	NA
PW-5	128 <sup>1</sup>	NA
PW-6	130 <sup>1</sup>	NA
PW-7	70 <sup>1</sup>	NA
PW-8	NA	NA
PW-9	132.88	NA
PW-11	134.83	NA
SG-1	162.1	NA
SG-2	162.3	NA
SG-3	NA	NA
SG-4	161.0	161.2
SG-5	161.1	161.3
SG-6	162.1	162.2
SG-7	163.1	163.2
SG-8	NA	163.3
SG-9	162.9	163.1
SG-10	163.5	163.5

<sup>1</sup>Approximate elevation.

NA - Measurement not available.

Specific protocols pertaining to well sampling, collection of in situ water quality data, collection of QA samples, sample handling, and documentation are spelled out in the Field Sampling and QA/QC Plan. All samples collected for metals analyses were filtered in the field within 6 hours of collection and preserved immediately afterwards with nitric acid. Oil and grease samples were collected with a bailer from the top 6 inches of the water column before purging in those wells which could be accessed with a bailer (the new monitor wells); otherwise, they were pumped. All other samples were collected from the pump discharge tubing, after well purging. Pumps used in purging and sampling monitor wells were all stainless-steel Grundfos Model SP2-10 equipped with stainless-steel coated Teflon discharge tubing.

Sampling pumps and tubing were completely decontaminated between wells using water from the Base demineralized water plant heated in a steam cleaner. To test the effectiveness of the decontamination procedure, a test was run prior to the first round of sampling in WESTON's Stockton, California lab. In this test, a spike of trichloroethylene (TCE) solution initially at a concentration of 0.080 mg/L was pumped through a sampling pump and 100 feet of Teflon discharge tubing for 10 minutes at a rate of 5 gallons per minute (gpm). The pump was then transferred to a tank of distilled water and pumped for 10 minutes. Samples were collected 3 minutes, 6 minutes, and 10 minutes after the start of distilled water pumping, and analyzed for TCE. Measured concentrations in these samples were 0.00025 mg/L in the first sample, and at or below the detection limit of 0.00012 mg/L in the second and third samples (Appendix L.6).

An additional 20 percent (approximately) of the total number of samples was collected for QA purposes. In the first round, field duplicates were collected from PW-1, PW-7, TW-12, MW-210, MW-260, MW-310, and MW-460, and full sets of field blanks were collected from each of the two sampling pump discharge lines after decontamination (FB-1 and FB-2). In addition, field blanks were collected for VOA analysis only from the end of the steam cleaner discharge line (FB-3), from the supply hose to the steam cleaner (FB-4), and from the demineralized water source spigot (FB-5). In the second round, field duplicates were collected from PW-5, PW-8, TW-16, MW-220, MW-240, MW-300, MW-330, MW-370, and MW-450. Two full sets of field blanks (FB-1 and FB-2) were collected from the two sampling pumps after decontamination.

Near the end of the second round, it was discovered that one of the pumps used to sample monitor wells was equipped with a faulty valve on the discharge tubing which might have introduced significant volumes of air into samples as they were being collected. Three special duplicates were collected from MW-250 to validate sampling methods. W-1 was collected with a Teflon bailer, W-2 with the pump equipped with the faulty valve, and W-3 with the pump equipped with a good valve. VOA results for W-2 were found to be as much as two orders of magnitude lower than W-1 or W-3 (see lab report in Appendix L). Fourteen wells suspected of having been affected by the faulty valve were purged and resampled from 10 to 12 April 1985, for VOA only. VOA results reported for these wells were obtained from analysis of the resamples. This problem should not have affected any of the other samples collected in the second round or any of the samples from the first round.

Sample containers and preservatives used are given in the field sampling and QA/QC Plan (Appendix G). Duplicates of all samples, including the QA samples, were collected and sent to OEHL at Brooks Air Force Base. All sample containers were labeled, and all ice chests shipped or transported to the laboratories were accompanied by WESTON chain-of-custody forms. In addition, a WESTON sample log sheet was completed for each well sampled. Copies of all chain-of-custody forms and sample log sheets completed for this investigation are provided in Appendices H and I.

#### 3.3.5.4 Surface Water Sampling

WESTON conducted two rounds of surface water sampling from 9 staff gage stations in the drainage ditches in the Main Base and South Sectors on 4 March 1985 and 3 April 1985. Specific sampling requirements and sampling protocols were spelled out in the Field Sampling and QA/QC Plan (Appendix G). In general, sample containers, preservatives, and documentation were the same as for groundwater samples. Surface water samples to be analyzed for metals were filtered in the field and preserved with nitric acid immediately afterward. Two field duplicates were collected in the first round, from SG-6 and SG-9, and two in the second round, from SG-5 and SG-7. Copies of the sample log sheets and chain-of-custody forms are included in Appendices H and I. Duplicates were collected and sent to OEHL at Brooks Air Force Base.

#### 3.3.5.5 Field Testing for Water Quality

During collection of all groundwater and surface water samples for laboratory analysis, grab samples from each location were gathered for field measurement of temperature, pH, and specific conductance (SC). These samples were measured within 6 hours of collection, using a VWR Model No. 55 pH meter and a YSI Model No. 32 SC meter. The results of these measurements are summarized for the first round in Table 3-12 and for the second round in Table 3-13.

Table 3-12

Summary of Field-Tested Water Quality Parameters  
Round 1 (22 January - 1 February 1985)

Well Number	Temper- ature °C	pH	Field Specific Conductance (umhos/cm)	Specific Conductance Adjusted to 25°C (umhos/cm)
MW-210	19.2	7.5	421	480
MW-220	20.0	7.2	460	510
MW-230	15.1	7.3	241	300
MW-240	16.4	7.1	285	340
MW-250	16.5	7.5	472	570
MW-260	16.8	7.2	627	750
MW-270	13.9	7.5	522	670
MW-280	14.6	8.1	336	420
MW-290	19.2	8.0	350	390
MW-300	18.4	7.7	416	480
MW-310	16.5	7.6	412	490
MW-320	17.5	7.8	273	320
MW-330	18.5	8.4	255	290
MW-340	18.0	8.0	243	280
MW-350	15.8	7.9	309	380
MW-360	16.3	7.6	480	580
MW-370	16.6	7.9	324	390
MW-380	21.3	7.2	487	520
MW-390	15.6	7.8	258	320
MW-400	16.0	7.5	320	390
MW-410	18.0	6.9	500	580
MW-420	20.3	7.7	304	330
MW-430	14.9	7.9	384	480
MW-440	22.0	7.9	400	420
MW-450	19.8	7.5	329	370
MW-460	15.2	8.1	206	250
MW-470	17.8	8.5	238	280

Table 3-12  
(continued)

Well Number	Temperature °C	pH	Field Specific Conductance (umhos/cm)	Specific Conductance Adjusted to 25°C (umhos/cm)
New PW	18.4	7.3	230	360
PW-1	18.4	7.8	230	260
PW-2	18.9	7.9	222	250
PW-3	17.8	7.6	295	340
PW-5	19.2	7.7	202	230
PW-6	18.6	7.5	206	230
PW-7	19.3	7.5	256	290
PW-8	18.3	7.7	239	270
PW-11	17.1	7.4	189	220
TW-12	17.3	7.4	580	680
TW-13	20.1	7.1	573	630
TW-14	20.1	7.2	489	540
TW-15	19.2	7.1	564	640
TW-16	20.8	7.3	427	460
TW-17	20.3	7.0	459	510
TW-18	19.5	7.3	355	400
TW-19	18.5	7.6	280	320
SG-1	10	8.6	370	520
SG-2	7.6	8.8	560	840
SG-3	9.8	8.0	630	890
SG-4	9.5	8.0	270	380
SG-5	10.8	7.5	240	330
SG-6	8.5	7.2	210	310
SG-7	14	7.4	180	230
SG-8	13	7.4	230	300
SG-9	13	8.3	210	270

Table 3-13

Summary of Field-Tested Water Quality Parameters  
Round 2 (1-12 April 1985)

Well Number	Temper- ature °C	pH	Field Specific Conductance (umhos/cm)	Specific Conductance Adjusted to 25°C (umhos/cm)
MW-210	21.5	6.9	10 <sup>1</sup>	10 <sup>1</sup>
MW-220	23.8	6.9	464	480
MW-230	21	7.0	281	300
MW-240	21.3	6.3	278	300
MW-250	19.6	7.1	571	640
MW-260	20.8	7.2	693	750
MW-270	20.8	6.8	631	690
MW-280	21.7	6.9	380	410
MW-290	22.9	7.6	330	340
MW-300	21.8	7.8	390	420
MW-310	22.2	7.4	393	420
MW-320	22.8	8.2	220	230
MW-330	19.7	7.7	240	270
MW-340	21.8	7.6	220	230
MW-350	22.7	8.2	305	320
MW-360	20.5	7.1	510	560
MW-370	20.7	7.2	381	420
MW-380	21.5	7.4	458	490
MW-390	20.5	6.8	240	260
MW-400	24.0	7.7	359	370
MW-410	22.0	6.6	550	580
MW-420	21.6	7.5	306	330
MW-430	23.2	7.0	387	400
MW-440	23.5	7.7	391	400
MW-450	20.6	7.6	148	160
MW-460	21.3	7.9	194	210
MW-470	23.4	7.9	220	230

<sup>1</sup>Measured value assumed to be in error.

Table 3-13  
(continued)

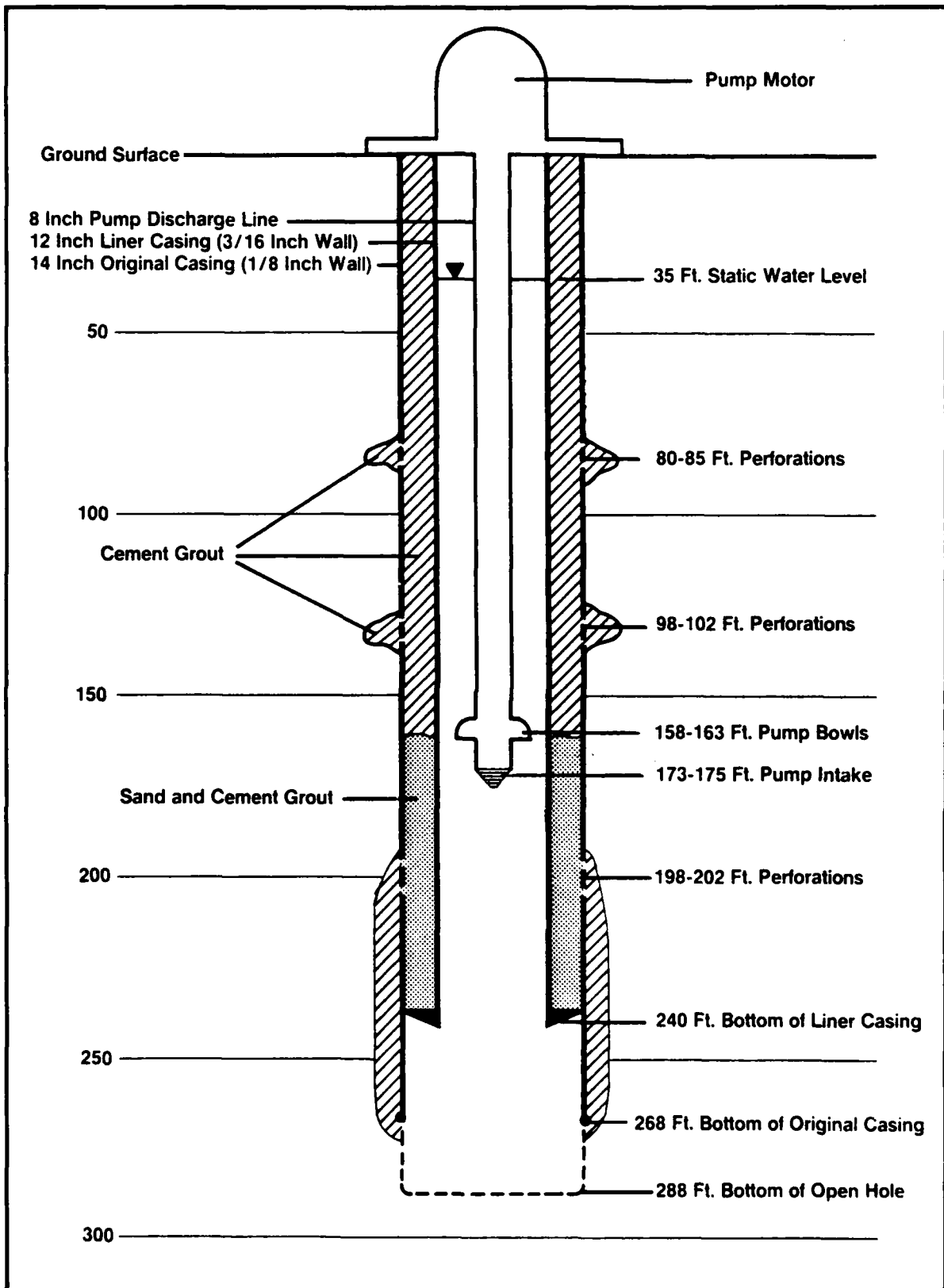
Well Number	Temperature °C	pH	Field Specific Conductance (umhos/cm)	Specific Conductance Adjusted to 25°C (umhos/cm)
New PW	27.9	7.1	296	280
PW-1	26.3	7.2	286	280
PW-2	26.2	7.5	280	270
PW-3	26.4	7.4	276	270
PW-4	24.9	7.5	269	270
PW-5	24.5	7.5	229	230
PW-6	24.6	7.6	231	230
PW-7	25.7	7.5	295	290
PW-8	25.5	7.5	271	270
PW-11	24.6	7.5	223	220
TW-12	22.4	6.9	570	600
TW-13	22.2	6.9	562	590
TW-14	21.6	7.0	470	500
TW-15	23.0	7.0	555	580
TW-16	22.5	6.7	438	460
TW-17	22.3	7.0	521	550
TW-18	21.7	7.3	346	370
TW-19	23.5	7.4	260	270
SG-1	26.7	8.6	316	310
SG-2	23.6	9.8	144	150
SG-3	23.7	10.1	422	430
SG-4	27.1	8.4	105	100
SG-5	28.0	8.5	143	140
SG-6	23.0	8.9	203	210
SG-7	26.1	9.1	293	290
SG-8	27.9	9.0	269	260
SG-9	27.5	8.9	310	300

### 3.3.6 Pilot Test Operations at PW-3

The proposed pilot test operations at PW-3 (described in Sub-section 3.1.2.1) were initially delayed because in October 1984 this well was no longer in production, and was not equipped with a discharge line to bypass the Base water distribution system.

After a bypass line was installed on the turbine pump discharge by WESTON's subcontractor, the well was pumped on 12 to 13 November for 24 hours at 400 to 500 gpm and sampled at the end of that period. Water levels were monitored in both PW-3 and adjacent TW-14. The turbine pump was removed on 13 to 14 November, the casing was cleaned, and a gamma log was run to identify zones of differential permeability in the formation behind the well casing. Inspection of the casing by means of a television logging tool on 19 November and again on 28 November 1984 indicated that the existing 14-inch well casing might be leaking, either due to damage or to separated casing joints, at one or several points between depths of 150 and 170 feet. On the basis of this information, the work scope for this subtask was altered, in consultation with OEHL/TS, to include installation of a nominal 12-inch liner casing following perforation of the 14-inch casing. The 14-inch casing was perforated in three intervals (80 to 85, 128 to 132, and 197 to 202 feet) on 10 December 1984, and a 12-inch diameter steel liner casing was installed to a depth of 240 feet the same day. A few cubic feet of sand and cement were tremied into the annulus immediately to form a bridge between the casings in the interval between 235 and 240 feet and to reinforce the rubber packer used to seal the annulus between the 14-inch and the 12-inch casing. Initial attempts to seal the annulus and the formation opposite the perforations with bentonite slurry and neat cement grout were unsuccessful, as these materials exited the annulus through the 197 to 202-foot perforations and eventually by-passed the lower 68 feet of the 14-inch casing into the open well bottom. On 18 December the 197- to 200-foot perforations were bridged by tremieing sand followed with cement to 160 feet, and on 19 December the remaining annular space was successfully sealed to the surface with neat cement. Figure 3-22 is a schematic of the current construction of production well 3.

Between 7 and 10 January 1985 a cable tool rig was used to drill out excess sand and cement from the well and to restore a significant yield from the formation in the open bottom by developing the well with a large-capacity bailer.



**FIGURE 3-22 SCHEMATIC OF REHABILITATED BASE PRODUCTION WELL 3**

On 11 January 1985 the well was test-pumped for 2 hours and sustained a yield of 420 gpm with 11 feet of drawdown. A recovery test was performed at the end of the pumping period. After test pumping, a sample was collected from a depth of 281 feet and the bottom of the well was sounded at 288 feet (open 20 feet below the bottom of the 14-inch casing and 6 feet deeper than at the outset of this subtask). The turbine pump was reinstalled on 16 January 1985, and the long-term test-pumping and sampling program associated with this subtask was begun on 17 January 1985. The well was pumped a total of 108 hours per week (12 hours a day except Sundays and Mondays, when it was pumped for 24 hours each day) for a 4-week test period. The estimated average pumping rate during this period was 1,300 gpm. The sampling schedule, starting from the time of turbine pump start-up, was the following: 15 minutes, 3 hours, 12 hours, 3.5 days, 1 week, 2 weeks, 3 weeks, and 4 weeks. All samples were analyzed for VOA. Four replicate samples for analysis of TCE only were also collected at 4 weeks.

Results of the gamma log, the television log, and the recovery test have been assembled in Appendix E. Further information on the hydrogeologic and chemical conditions encountered in the PW-3 pilot test operations have been incorporated into the discussion of results in Subsection 4.5.

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